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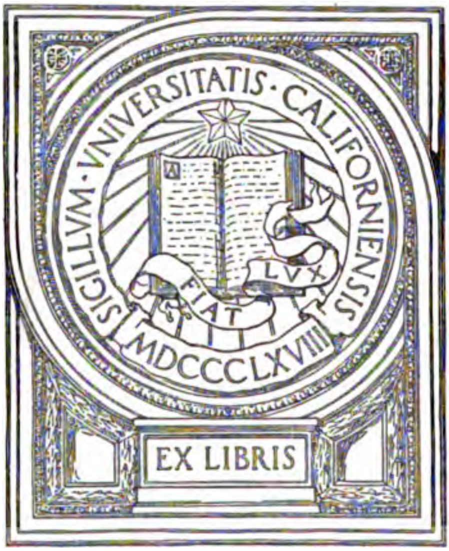

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DRYING MACHINERY AND PRACTICE

BY THE SAME AUTHOR.

DRYING PROCESSES AND PATENTS.

A Companion Work to this Volume, treating of Processes and Patents for Drying and Desiccating.

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CRUSHING AND GRINDING MACHINERY PRACTICE.

A Handbook on the Machinery used in Crushing and Grinding Operations on all classes of materials.

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DRYING MACHINERY AND PRACTICE

A HANDBOOK ON THE THEORY AND PRACTICE OF DRYING AND DESICCATING, WITH CLASSIFIED DESCRIPTION OF INSTALLATIONS MACHINERY, AND APPARATUS

INCLUDING ALSO

A Glossary of Technical Terms and Bibliography

BY

THOMAS G. MARLOW

GRINDING, DRYING, AND SEPARATING MACHINERY SPECIALIST

WITH NUMEROUS TABLES, PLATES, AND ILLUSTRATIONS

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PREFACE

This handbook is intended to give an insight into the art of Drying, and descriptions of typical designs of the machines and apparatus used in Drying and Desiccating.

In order to do so the general principles which govern the various methods of removing moisture (water) from all kinds of materials have been briefly stated, followed by a summary of the several methods employed, together with the tables of calculations necessary in deciding the requisite capacities. Then the apparatus, machinery, and installations of plant are described and illustrated by modern typical examples. These have been chosen by the makers as worthy of bearing their name, and the descriptions have in every case been passed by them.

The innumerable kinds of material which have to be dried, the varying degrees to which this dryness is needed, and the many types of apparatus which are in use open up a vast field for research. As it is quite impossible to deal exhaustively with such a wide subject, or while retaining a due proportion to exhaust even one section, there has been added a Bibliography so that reference can be made to the entire literature on any desired point. The Glossary of Terms appeared to be an absolute necessity in the absence of any authoritative manual on the subject, and it is hoped this may form a basis for future use of the terms and classifications.

The fact that no one had written a book in either English, German, or French on any particular subject

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would appear to indicate that that subject was of small consequence, or that there were very few people interested in it. So far from this being the case, drying machinery is of great consequence to a very large number of important trades; while the practical interest shown in the present volume by those having experience in this branch of engineering proves that the book will be welcome. This has been a very great encouragement to the author in endeavouring to complete this work in the intervals of a busy professional career.

Having received such generous assistance the author would have preferred to acknowledge each instance, but as the list would include the proprietor and the chief of the technical department in the case of all the firms mentioned, this is impossible, but to omit the names of Mr Wilfrid N. Robinson, of Thos. Robinson & Son, Ltd.; Mr Geo. A. Mower, of Sturtevant Engineering Co., Ltd.; Mr H. J. Pooley, of Geo. Scott & Son, Ltd.; Mr C. E. Hodgkin, of Pulsometer Engineering Co., Ltd.; Mr W. J. Jones, of Thresh Disinfector Co., Ltd.; Mr A. B. Lennox; Mr E. R. Sutcliffe, of Sutcliffe, Speakman, & Co., Ltd.; Mr R. Williamson, of Pott, Cassels, & Williamson, would be gross ingratitude.

If this work is worthy of the support it has received, and meets with the success which has been foretold in many encouraging letters to the author, then a new edition will soon be required, and he will appreciate any communications as to new designs of machinery and further data, so that the utility of the book may be increased.

THOS. G. MARLOW.

138 Telford Avenue,
London, S.W.

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DRYING MACHINERY AND PRACTICE

CHAPTER I

INTRODUCTORY

Reasons for Drying—Degrees of Dryness—Humidity of the Air—Hygrometers—Hygrodeik—Psychrometer—Dryness of Solids—Suggested Terms—Moisture Gauges—Robinson Gravimeter—Reform Moisture Tester—Technical Terms—Tables and Data—Bibliography—General Principles—Natural Drying—A Shower of Rain—Artificial Drying—Mechanical Drying—Absorption—Evaporation—Diffusion - - - 1-13

Reasons for Drying.—The reasons for drying are many and various, as are the results obtained; among others may be mentioned:—

1. To preserve the material by preventing physical and chemical changes. There are innumerable instances of this—hay, fruits, hops, tobacco, timber, leather, rubber, fish, fowl, meat, &c.

2. To prepare the material for processes of manufacture or manipulation, for instance:—

Roasting, as copper ore, bricks, pottery ware, cement slurry, &c.
Dry Grinding, as gold ore, coal, cement, limestone, sandstone, corn, &c.
Magnetic Separating, as tin ore, brass slag, iron ore, &c.
Pneumatic Separating, as gold ore, silver ore, tin ore, &c.
Impregnating or *Sterilising*, as in timber seasoning, asphalting stones, preparing bone meal, &c.

3. To remove the water needed during previous operations. Drying clothes after washing, wools after scouring, woollen

and cotton fabrics after dyeing, coal after washing, coke and ashes after quenching, sewage sludge after the addition of the lime.

4. To obtain a more even sample or one capable of accurate measurements. In all quantitative chemical operations, whether on a large or small scale, as the water in a wet or moist material is an unknown and practically immeasurable quantity, it is usual to dry the various ingredients before mixing them in their respective proportions. Mixing is especially difficult in the case of dry and damp materials, it being almost impossible to obtain an even blend, whereas by drying all the ingredients the operation is comparatively simple.

5. To save the weight of an unnecessary ingredient and facilitate transport, thus lessening the cost of packing, carriage, and freight, *e.g.*, timber, coal, coke, peat, &c.

6. To retain desirable moisture by surface drying, thus forming a thin crust or covering of a more impermeable nature than the mass of the material. For instance, by removing 3 to 5 per cent. of the moisture from the surface of soap bars, the imperceptible skin or crust prevents the evaporation of the 35 per cent. of moisture remaining in the bulk of the bars. Similarly with pastilles and chocolates, the surface drying retards the interior drying.

7. To give clearness and pureness to the surface and skin, as in sardines after washing and before boiling in oil. The boiling would remove the water, but the product would lack its characteristic crispness and piquancy. Fish, fowl, and meat are for the same reason surface dried more or less after being washed previous to roasting and frying.

8. To complete the operation in hand or process of manufacture, this being similar to 3, but usually carried to a greater degree, as in paper, pasteboard, pigments, barytes, paintings of the oil, varnishes of the solvent, writing with blotting paper, and numerous other cases.

9. To save fuel or prevent loss of heat, thus wood, coal, and other combustibles are sometimes dried previous to feeding into the furnace to prevent the loss of heat and temperature which would otherwise occur, the vaporisation of their water absorbing a large number of heat units.

10. To prevent injury to health or goods, as in the case of

moisture laden or vapour laden air of textile factories, evaporating rooms, &c.

Degrees of Dryness.—A small amount of consideration of the various purposes served by drying processes makes apparent the wide range of degrees of dryness and the varying conditions to which we apply the term dry. This vagueness partly arises from the difficulty of measuring the actual amount of water present in any given case. By means of Hygrometers the amount in the air of any room or locality may be calculated, but to measure the relative or actual amount in any other substance nearly always requires the water to be entirely removed and the loss of weight noted. By this laborious process there is still obtained only the data for the actual portion dried, and owing to the nature of the case every other portion may be, and probably will be, different.

The varying capacity of different substances for absorbing moisture increases the difficulty of expressing the presence or absence of water in relative or absolute terms without actual weights.

Humidity of the Air.—For instance, air can be gauged as to its dampness or humidity, but owing to its vast capacity it cannot be used as a guide to other materials. Air is thus usually classified from the saturation point as 100 per cent., *i.e.*, at saturation point it carries 100 per cent. or all of the moisture it is capable of carrying at that temperature. Then

at	100	per cent.	the air is said	to be	saturated,
„	85	„	„	„	damp,
„	65	„	„	„	moderately dry,
„	50	„	„	„	dry,
„	35	„	„	„	very dry,
„	25	„	„	„	extremely dry.

By raising the temperature of the air a few degrees these percentages and comparisons are swept away, as the same volume of air can contain or carry a larger quantity and hence the percentages are lower. (See Table XXII.)

Hygrometers.—These degrees of humidity of air are measured by means of hygrometers, of which there are various types. Those mostly in use consist essentially of two thermometers. One thermometer has an exposed but dry bulb, and simply indicates the temperature of the air. The second thermometer has its bulb covered with thin muslin and kept wet. The evaporation of this moisture absorbs the heat from the bulb, which registers a lower temperature than the dry bulb thermometer. The temperature in the wet bulb thermometer falls in proportion to the amount of evaporation. The amount of evaporation is dependent on the dryness of the air. Hence the greater the fall in temperature the more dry the

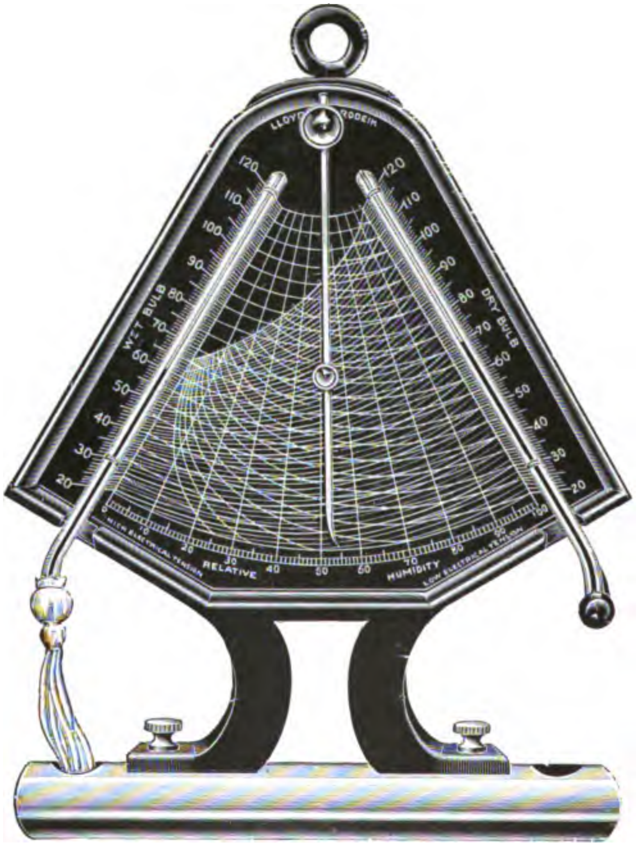

FIG. 1.—HYGRODEIK.
(Cambridge Scientific Instrument Co., Ltd.)

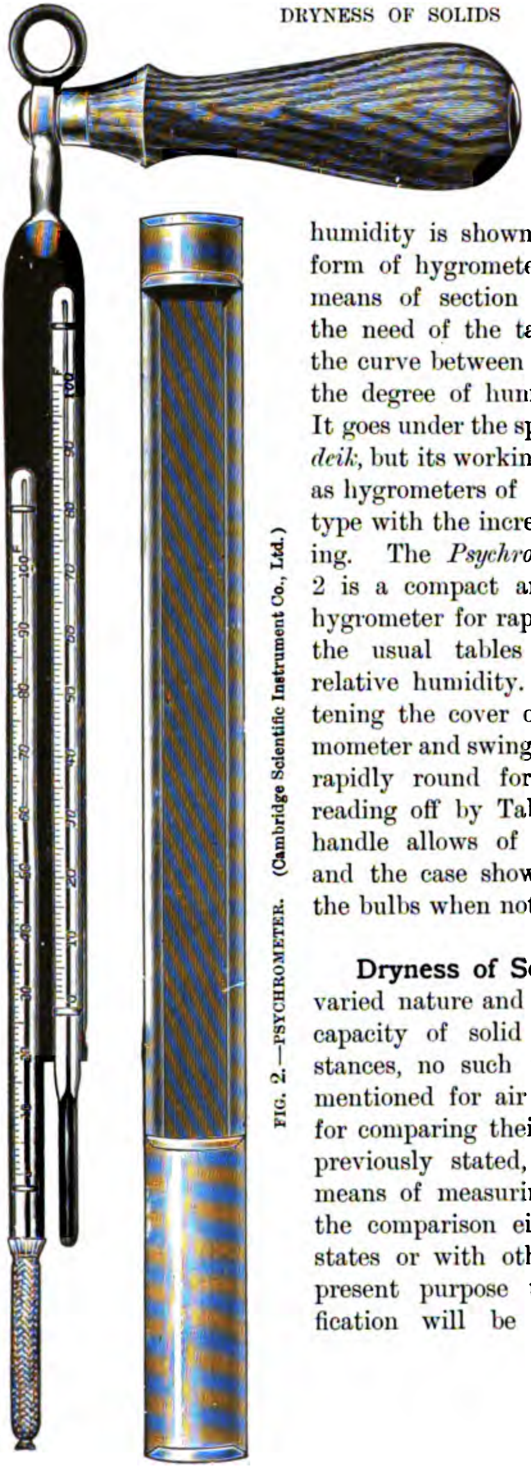

FIG. 2.—PSYCHROMETER. (Cambridge Scientific Instrument Co., Ltd.)

air. Tables have been compiled by which on noting the two temperatures the degree of humidity is shown (see page 73). The form of hygrometer shown in Fig. 1 by means of section lines dispenses with the need of the tables, as by following the curve between the two temperatures the degree of humidity is clearly read. It goes under the special name of *Hygrodeik*, but its working is exactly the same as hygrometers of the wet and dry bulb type with the increased facility of reading. The *Psychrometer* shown in Fig. 2 is a compact and accurate type of hygrometer for rapid work, but needing the usual tables for computing the relative humidity. It is used by moistening the cover of the wet bulb thermometer and swinging the Psychrometer rapidly round for a few times, then reading off by Table IX. The swivel handle allows of ready manipulation, and the case shown at side safeguards the bulbs when not in use.

Dryness of Solids.—Owing to the varied nature and moisture assimilating capacity of solid and semi-solid substances, no such percentages as those mentioned for air could be fixed upon for comparing their several states. As previously stated, there is no ready means of measuring on which to base the comparison either with their own states or with other bodies. For the present purpose the following classification will be convenient, without straining the terms much out of their generally accepted meanings:—

1. *Soaked* or *water-logged.*—When the water is dispersed abundantly throughout the mass or in the pores of the substance.

2. *Wet.*—When the water is abundant, but mainly on the surface, or mixed with the particles.

3. *Unwatered.*—When the surface water and free water of open materials is removed.

4. *Damp.*—When the moisture is apparent without touching the substance.

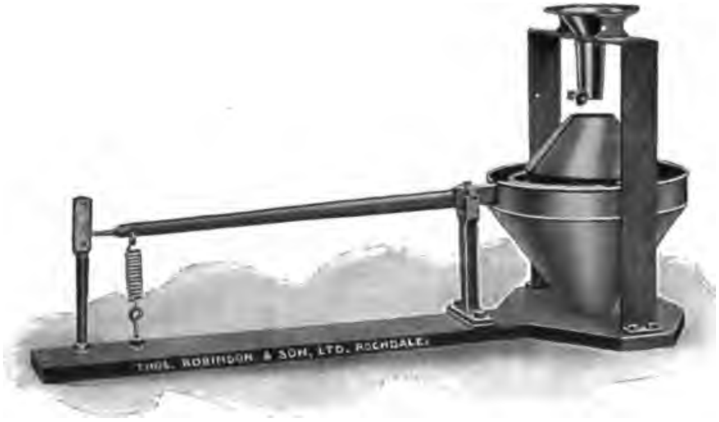

FIG. 3.—GRAVIMETER (PATENT). GENERAL VIEW.
(T. Robinson & Son, Ltd.)

5. *Moist.*—When the moisture cannot be seen, but is apparent to the touch.

6. *Dry.*—When no moisture is apparent to the touch, but the mass contains the normal characteristic moisture of its composition.

7. *Dried.*—When some of the normal moisture has been abstracted.

8. *Desiccated.*—When all the free or uncombined moisture which has been held as a chemical mixture has been abstracted.

9. *Dehydrated.*—When the moisture held in chemical combination has been removed.

These nine divisions will give a wide classification, and although it may not meet every case in a perfect definite manner, it will assist to form a more tangible idea of the subject and operations entailed.

Moisture Gauges.—The proportion of moisture in solid bodies is frequently of vital importance in maintaining a regular product, and especially is this difficulty felt with substances which, while they are more or less hygroscopic, are obtained from widely differing climes, such as wheat. In such cases the moisture may be too much or too little, and in Figs. 3 and 4 are shown a compact *Gravimeter* or instrument for detecting the varying moisture in equal bulks by the slight variations in the weight of such bulks. From the section (Fig. 4), it will be seen that the corn is fed into the fixed nozzle, and falls into the brass receptacle, which is always kept full. This receptacle is balanced on knife edges upon the scale arm. Thus any variation in its load produces an increased movement at the end of the scale arm which is at once noticeable. The adjustable spring meanwhile acts as a safeguard to prevent undue movement, counterbalancing the receptacle and its load. A very accurate and rapid indication is thus kept of the condition of the bulk as to weight, and therefore as to its condition in regard to moisture.

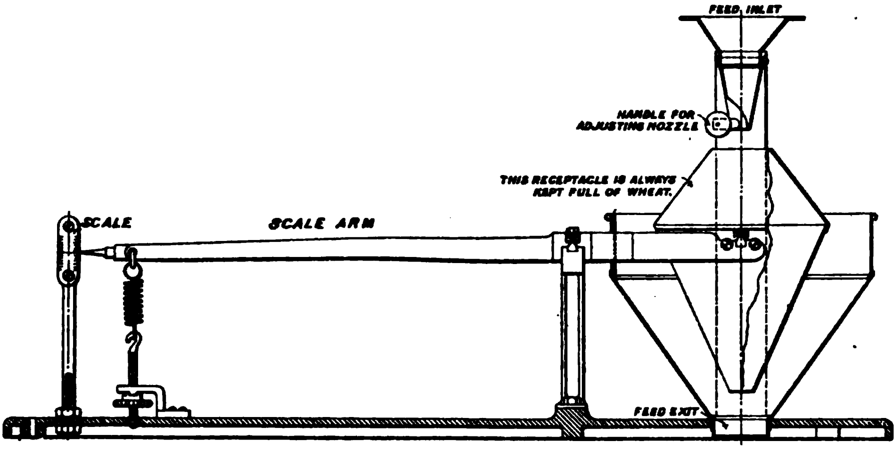
FEED INLET
HANDLE FOR ADJUSTING NOZZLE
THIS RECEPTACLE IS ALWAYS KEPT FULL OF WHEAT.
SCALE
SCALE ARM
FEED EXIT

FIG. 4.—GRAVIMETER (PATENT). SECTIONAL ELEVATION.
(T. Robinson & Son, Ltd.)

To actually test the proportion of moisture in a sample is a more complicated operation, and in Fig. 5 is illustrated one of the simplest forms of the necessary apparatus. The "*Reform*" *Moisture Tester* is specially designed for wheat, corn, flour, bran, malt, hops, and similar small organic bodies. As will be seen from the illustration, it consists of a receptacle for the sample, a condenser for depositing the vapour, and a graduated collecting tube to measure the amount of water. In order to utilise these the feed funnel and feed cock are necessary. While the thermometer gives indication of the temperatures, the heating shown is by a special spirit burner, but, of course, may be by any convenient method. The procedure of working requires great care in manipulation, as with measuring the quantities and noting the time, but briefly may be thus summarised. Into the receptacle is placed an exact quantity of oil and turpentine-toluol mixture quite freed from water. To this add a weighed quantity of grain, and well shake. Then heat to 180° Cent. for a definite time. Add a fixed quantity of the turpentine-toluol mixture, and reheat to 200° Cent. Remove the heater and let the whole apparatus cool down. Gauge the water collected into the glass collector. The quantities used vary, of course, with the sample, as also the temperatures. This simple apparatus and the procedure briefly stated may give some idea of the difficulty of and delicacy required when testing the moisture in solids.

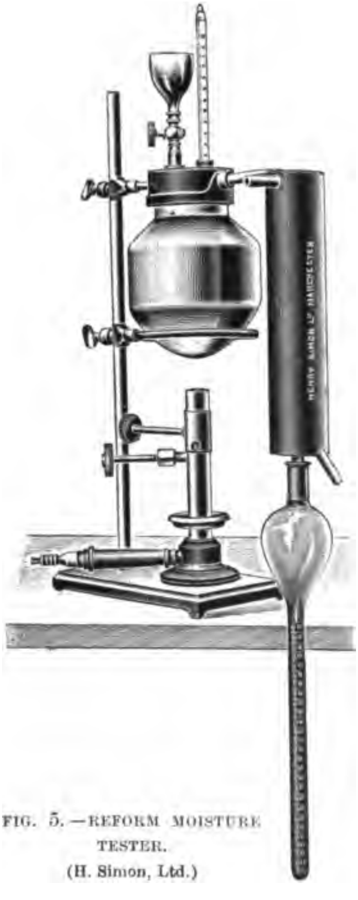

FIG. 5.—REFORM MOISTURE TESTER.
(H. Simon, Ltd.)

Technical Terms.—The terms used in connection with drying and desiccating are nearly all in use associated with other operations. The exact significance, however, is not always the same as in relation to drying. Many terms are also used vaguely for quite different operations and articles by individual users and makers. Hence the Glossary of terms has been added to define the meaning of the various terms as applied in this work in connection with drying operations and drying machinery. While full consideration has been given to the authoritative meaning of the words used as terms given in the standard dictionaries, and usually obtaining in current literature, the explanations here given relate to drying solely, and in all cases it is advisable, when in doubt, to refer to the Glossary, where the term is explained.

Tables and Data.—The tables and data are mostly given in British units as being more readily understood and realised by the general reader, and more appropriate in the present work, which is believed to be first on this subject written in the English language. There are many valuable papers on the principles and machinery of drying stored away in the records of the several societies associated with engineering and chemistry, also there are some very detailed books of data written in German.

The British units have many advantages, although the metric system has attractions for those who have trained themselves to think in metres. Further, it appears quite inadvisable to compel a study of the metric system on those who desire to learn about drying. A table of comparative values will be found in the Glossary for the convenience of reference and comparison.

The methods of obtaining these tables and data, or the formulæ for checking them, form no part of the plan of the present work; when desired, these can best be obtained from the standard text-books on Heat, Hydraulics, Pneumatics, &c.

Bibliography.—The bibliography of drying is not large, hence it is all the more necessary to keep a trace of such records as exist. The articles and notices entered are of very uncertain value in some instances, but those who are desirous of thoroughly investigating the subject will be able to use their own judgment as to the respective reliability of the various theories and statements. The author will be pleased to receive any additions to this section from those interested, as it will increase the value of future editions of this book, while giving credit to the work done by others in a field where much research is needed.

General Principles.

Drying may be performed in many totally different ways, according to the nature of the material to be dried and the degree of dryness desired in the product.

The term "dry" expresses a relative state, not an absolute condition. Still, whatever degree of dryness is considered, "to dry" means to remove a certain amount of liquid from the wet material under consideration. All the methods of separating the liquid from solid constituents are covered by the art of drying, and the main liquid which is considered in the present work is water in its various states.

Natural Drying.—A roadway or ploughed field during and after a shower of rain illustrates Nature's several methods of drying. So soon as the rain commences the ground is "wet." Some of the water will at once pass away through the ground, drying the surface by "drainage," while at the same time "soaking" the subsoil. Part of the water will run away down the various slopes, carrying with it more or less solid matter in suspension. This suspended matter will sooner or later fall and be drier because it has been separated from the water, in this case by "precipitation."

A portion of the water may come in contact with a wall of brick or stone which will help to dry the road by the wall taking up some of the water by "absorption."

By the "drainage," the "precipitation," and the "absorption," the road will have become "unwatered" or dried by removal of the bulk of its surface water although it may still be "damp" (contain water which can be seen) or may be "moist" (contain water which can be felt), or there may be puddles over impermeable spots which cannot drain away. On the rain ceasing the puddles and surface will promptly commence to give off their water to the atmosphere by evaporation. If there be a good wind this evaporation will be more rapid and more thorough, but in any case the road will thus become "dry." As the sun shines more brightly this evaporation will increase in speed and intensity, causing the clay and flotsam in the puddles to give up some of their normal moisture (or become "dried"), and at the same time produce "desiccation cracks" by the uneven contraction of the "dried" portions.

After this evaporation has proceeded for a time and thoroughly "dried" the surface to some depth, the lighter material on the road, such as leaves, petals, &c., will, if the sun remain powerful, give up all their free or uncombined water. They will shrink, shrivel up and become "desiccated." If some chemicals (*e.g.*, cupric sulphate) were exposed to this extra dry atmosphere the chemical affinity of their constituents for water is so small that they would give up the water held in combination and thus become "dehydrated."

The air subjected to the sun's heat though containing additional water is relatively "dried," as its degree of humidity is less compared with its capacity. If this vapour laden air meet a colder body or a colder current of air the burden of vapour becomes condensed into water and the air is "dried" by the "condensation." While if the vapour laden air is disturbed by a thunderstorm the vibrations will accelerate the deposit of any moisture in the air, the heat generated by the passage of the electric current will increase the vapour capacity and so dry the air by electricity.

Artificial Drying is only artificial to the degree of being a modification of the *method of procedure* in following natural drying processes. Mainly these modifications are to hasten the process, but are also largely to localise the result or economise the heat expenditure. While natural drying is uncertain in time and degree, artificial drying is attended with many disadvantages unless applied with the proper precautions necessitated by the characteristics or idiosyncrasies of the material to be dried and the product required.

Mechanical Drying.—If we are satisfied by removing the surface water or a proportion of the absorbed water in some materials, we can readily dry them to a considerable extent by purely mechanical means, *e.g.*, draining, filtering, filter pressing, and hydro-extractors. Each of these methods is efficient and economical under certain conditions and as applied to suitable materials. So each process will be briefly considered later and mainly as preparatory to drying of a higher degree.

Absorption.—Leaving out of consideration any water which may thus be removed by purely mechanical means, let us proceed to consider the elimination of the remainder or part thereof. This opens up a new proposition, because the water has no innate tendency to leave the material, and hence leads to the idea of applying some material which has more attraction for the water, thus removing it by absorption, instances of which we have after our daily bath, besides many other domestic and commercial processes too numerous to mention. This absorption, whether by towel, blotting-paper, sawdust, chalk, or charcoal, may be very efficient for its own particular application, but must of necessity be very restricted, and necessitates intimate contact with all parts of the materials to be dried.

There are also certain substances which have such a strong affinity for water as to promptly annex all available from the surrounding air and surrounding objects, though not in contact. If these substances are placed in closed rooms with the materials requiring to be dried, of course the water is abstracted from the less retentive material and assimilated by the more attractive. Instances of such substances are quicklime, calcium chloride, and oil of vitriol. For chemical and laboratory purposes they are often used, and given time they are powerful means of drying. But it needs small consideration to appreciate that their commercial use on a large scale is out of all reason, although it has been gravely recommended to use calcium chloride in drying-rooms for materials containing 30 per cent. of water, and holding from 4 to 6 tons of such materials.

Evaporation.—Proceeding to see how this water is to be readily removed from the material. The water is present in the form of a liquid. Now, according to the latest and best authenticated theories of the constitutions of bodies, all the molecules of this liquid, and all other liquids, are continually moving about among themselves, assuming new positions, and travelling from one part of the mass to another. The energy of these movements depends upon the amount of heat in the liquid. The molecules at the surface are continually taking heat from the surrounding atmosphere, and thus pass into vapour. On becoming a vapour its movements are amplified in extent and speed, with the result of it becoming more detached from the material, while tending to diffuse itself into the atmosphere. Hence it is apparent that in drying, the first step is to turn the water into vapour, and this can be done by heat, or in other words to dry

1. Heat the surface of the material, and so turn the water into vapour.

Diffusion.—Having heated the material, and thereby driven the water into vapour, there is now gas or vapour to be dealt with instead of a liquid. The vapour as such has more amplitude of molecular movement and greater tendency to diffuse into the surrounding gas or atmosphere, but at any given temperature only a certain weight of vapour can occupy a cubic foot. This amount is governed only by the elastic force of the vapour, and not by the presence or absence of air.

The pressure (or elastic force) of the surrounding vapour, however, puts a limit to this diffusion. They are practically antagonistic forces: the more heat in the vapour the greater its diffusibility; the greater the pressure of the vapour, the less it can diffuse. When the two balance, the air with which it is mixed has just as much vapour as it can hold—the air is saturated. Then there appear to be two alternatives—put in more heat or remove the pressure; but there is also a third, which is

2. Remove the air which contains the vapour.

This, then, solves the problem of drying, as by continuously warming the material its water is turned into vapour, and by removing this vapour as diffused, dryness can be obtained to any desired degree of perfection. Hence these are the two primary processes to consider in every drying proposition.

CHAPTER II

DRYING BY GRAVITATION

Drying by Gravitation. — Drainage—Sewage Farms — Sump-Holes — Coal Washeries—Briquette Factories—Dredging—Coke and Ash Quenching—Bucket Elevators—Sewage Screens—Unwatering Cylinders—Precipitation—Decanting—James' Patent Decanting Vessels—Settling Tanks—China Clay Works—Barytes Works—Gold Mining—Steel Settling Tanks—Filtering—Filter Frames—Vacuum Filter Pan—Continuous Vacuum Filters—Wilfley Continuous Vacuum Slimes Filter—Dewatering Filter—Ogle-Ridgway Vacuum Filter - - - - - - 14-23

Drying by Absorption.—Aqueous Affinity—Mixture—Efflorescence—Capillarity—Deliquescence—Hempel Desiccator—Air Absorption—Drops—Dye-House Practice - - - - - - - 23-26

Drying by Condensation.—When Advisable—Refrigeration—Cold Storage—Normair Vapour-Depositor—Direct Expansion Air-Cooler—Advantages of Condensation - - - - - - - - 26-29

Drainage.—Drainage is really drying on a wide scale, but many instances of drainage are outside our scope. Among the cases where advantage is taken of the water as a liquid to flow away from the solid may be mentioned the sewage farms of many large towns; the treated sludge being conducted on to prepared portions of the farm in the form of a more or less thick liquid, when the water percolates through the soil into a network of drains which conduct it into the nearest stream.

The "sump hole" into which the drains of the house or village delivered their contents in the "good old days," is a sample of this principle sadly misapplied. For when it did become dry its smell was strong but not sweet, and the odour reached up to the heavens. It is difficult to appreciate such relics of old times when one remembers the strange coincidence of the opening of these stench holes with a large increase of infantile deaths, and sore throats for elders.

In coal washeries and briquette factories, too, the cleansed coal is conveyed into large hoppers or bunkers, where in about

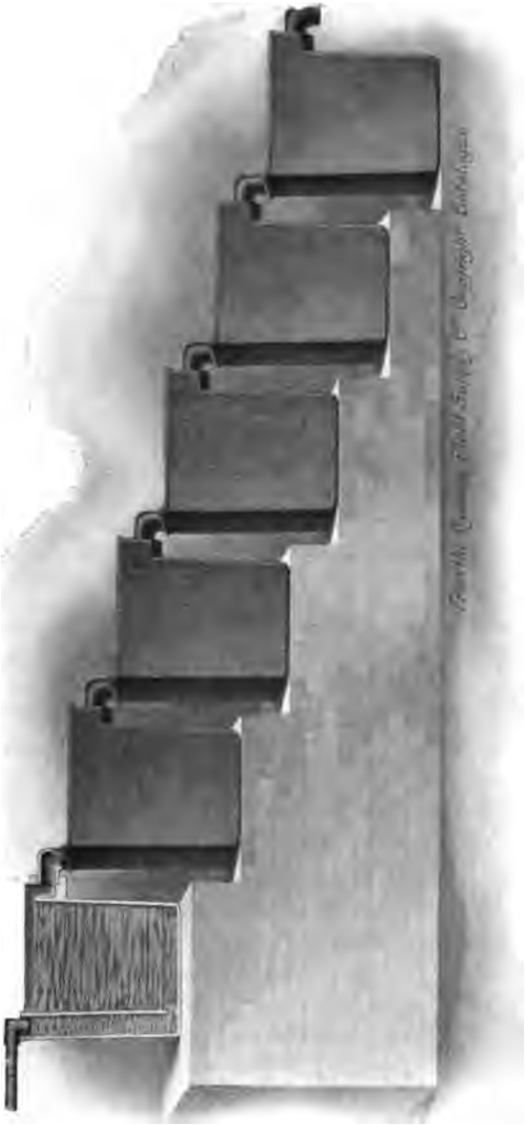

FIG. 6.—JAMES' (PATENT) DECANTING VESSELS.
(The Cyanide Plant Supply Co.)

twenty-four hours it will part with 10 to 20 per cent. water, thus preparing it for the breaker.

Dredging with grab or central ladder is also much assisted by the drainage of the water from the shingle when placed in the barges or on the bank. At gas works and power stations, the coke and ashes when drawn from the retorts or furnaces are quenched with copious supplies of water, and then conveyed to bunkers, which allow the surplus water to drain away. Of course the heat causes a large amount of the water to evaporate, but necessarily there is much more used to perform the required quenching.

The drainage is assisted mechanically in several instances. The wet material is raised by an elevator or conveyor, made with perforated buckets, which allow the water to pass away during transit. The solid matter which floats on a stream or current at sewage works, &c., is intercepted, raised, and drained by means of a metallic conveyor band working under the surface, and rising above it.

In coal washery cylinders the washed coal is slightly elevated and carried forward after leaving the water. This movement is performed by blades on the interior of a revolving cylinder, and allows the coal to drain sufficient to leave the cylinder "unwatered," that is, free of surface water.

Precipitation.—At many works there are instances of precipitation, where the mixture is allowed to settle in tanks or vats so that the heavier material sinks to the bottom. The surplus water floating to the top is either drained or decanted off, leaving the solid matter much drier (Figs. 6, 7, and 8).

The *Decanting Vessels* (Fig. 6), while specially designed for treating gold ores, are in a form convenient for many chemical purposes. They are made of cast iron or sheet iron enamelled inside. As will be seen from the section of the first vessel (or box), the supply, though from the top, is conducted downwards in order to rise through the enamelled screen. The screens are supported on frames (enamelled), and have the zinc above them. The overflow lip leads by a spout to the next box, and so on throughout a series of six or more. In use, after the removal of the zincs, they are usually emptied by the suction pipe of the filter press, but can be also cleared by a plug at bottom if desired. This system of upward filtration is found very effective in precipitating the solid matters in the water or slimes.

In china clay works the mixture, in the condition of thin mud, is pumped into the "settling tanks" or stone-lined pits, and the water returns by overflow into the sump again. During the process of levigating barytes, the mixture passes through a series of these settling tanks placed stepwise, so that the overflow of the upper ones passes through the lower by gravity, the finest qualities of the barytes gradually precipitating. At chalk works a similar method of precipitation is employed, but the final tank is of a porous nature, and so completes the operation by drainage.

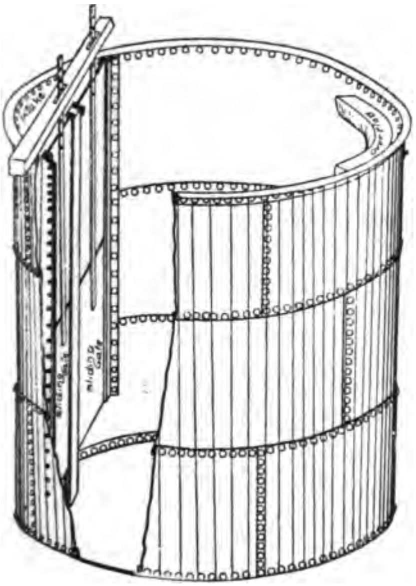

FIG. 7.—STEEL SETTLING TANK, SIDE FEED.

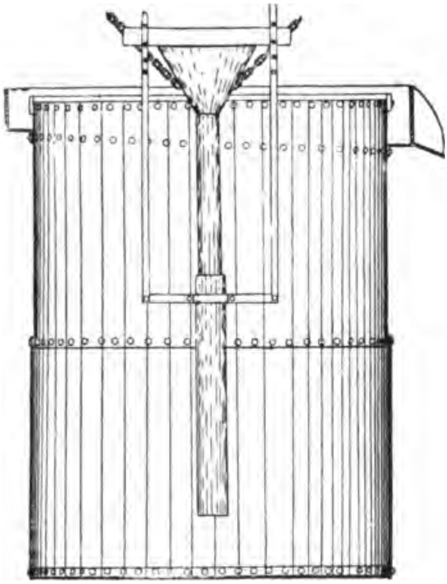

FIG. 8.—STEEL SETTLING TANK, CENTRE FEED.

(Wilfley Mining Machinery Co., Ltd.)

Settling tanks of steel plate are often used in gold and other mining for precipitating the material after being wet ground in the stamps. For precipitating the fine slimes, two designs of such tanks are shown in Figs. 7 and 8. They are each used for the same purpose. Fig. 8 for smaller plants has the feed at the funnel, the slimes pass down the pipe to near the bottom of the tank. The water overflows into the launder at the top, and is regulated by passing over a wooden strip, which is dressed according to the settling in the tank. The central pipe is adjustable in height to allow of free flow as the slimes settle. The intake in Fig. 7 is at the top, but by the partition and slide gate is conducted to the bottom of the tank. The slide and the overflow are adjustable to the state of the tank, and allow of decanting after the tank is about half full. This form is more usual in the larger plants. Each type has draw-off plugs at different heights to allow of the surplus water being removed.

Filtering, as used in drying, is accelerated drainage The wet pigments from the precipitating tanks are thrown on to a filter constructed of a sheet of calico loosely stretched over a skeleton framework; the water drains through while the pigment remains on the top of the cloth, the speed and thoroughness of the drying depending on the texture and quality of the filter cloth as well as the condition and nature of the material.

In some colour works and chemical works this form of filter is replaced by a more expeditious design called a *vacuum filter.* A hemispherical vessel is divided into two parts by a perforated plate, which forms a false bottom. The top portion is open, and the perforated plate is covered with a filter cloth, and the material placed thereon. The bottom portion being closed, the water drains into it, and it is connected to a vacuum pump, which greatly accelerates the process while leaving the solid matter on top much drier than by ordinary filtration.

A very great development of vacuum filtering is shown in the *Wilfley Continuous Vacuum Slimes Filter* (Fig. 9), which, while originally designed for slimes of gold ores, is adaptable to many other drying purposes. It is particularly suited for "unwatering" semi-solids, and in its usual form for general purposes is called a *"dewatering" filter.*

Essentially this machine consists of a drum with its periphery covered by a filter cloth, and its interior exhausted by a vacuum pump. The drum is partly submerged in a tank of the material to be filtered, and the suction of the pump draws the water through the filter cloth, leaving a coating of the more solid ingredients on the outside of the cloth. As the drum revolves, a continuous coat is thus formed on the whole of the cloth, and so soon as this coat becomes thick enough it meets an adjustable skimmer which removes the surplus without coming in contact with the cloth. Thus the material forms an additional filtering medium and guards the cloth from wear.

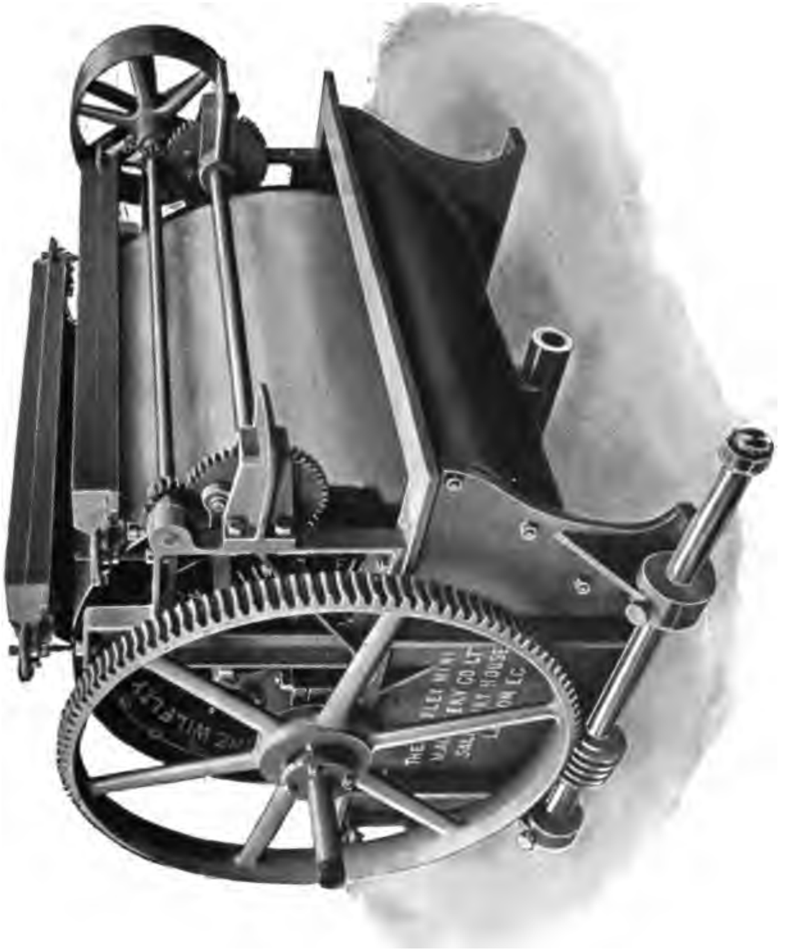

FIG. 9.—CONTINUOUS VACUUM SLIMES FILTER.
(Wilfley Mining Machinery Co., Ltd.)

From the illustration it can be seen that the exhaust is by a pipe which passes through the trunnion to the inside of the drum. The drive is by worm and wheel reduction gear, as the speed is very slow, dependent on the nature of the material.

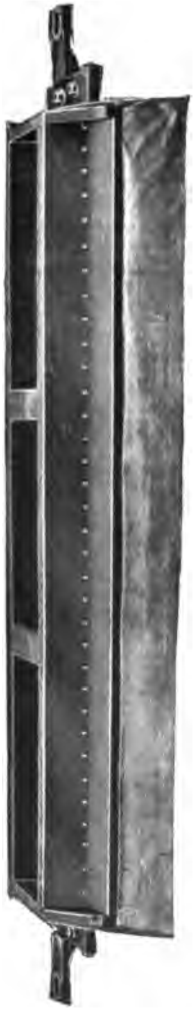

FIG. 10.—WATER DISTRIBUTING TROUGH.
(Wilfley Mining Machinery Co., Ltd.)

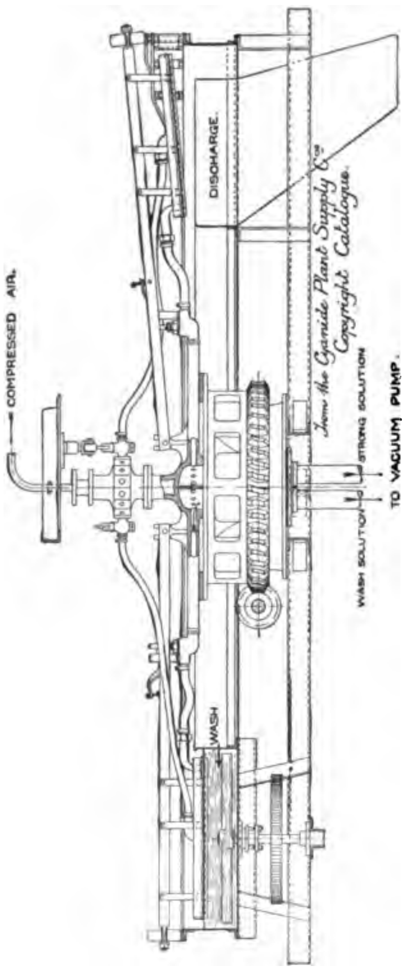

FIG. 11.—OGLE-RIDGWAY VACUUM FILTER (PATENT). SECTIONAL ELEVATION.
(The Cyanide Plant Supply Co.)

The power required is remarkably small, being only about 1 H.P. apart from the pump, which is not shown.

The remaining gear is not essential or necessary in all cases. The two longitudinal shafts shown are for producing an agitating motion in the material when it is of too heavy a nature, while the two longitudinal troughs shown above the shafts are for washing the partly dried material when it contains some ingredient which it is desirable to displace. Fig. 10 shows the construction of these troughs.

The space occupied is small, about 7 ft. by 5 ft. and 5 ft. high. The vacuum advisable varies from 10 to 14 in. The capacity varies with the material, but for gold slimes of usual fineness the vacuum filter will treat 35 to 60 tons (dry weight) in twenty-four hours, and leave about 15 per cent. of residual moisture.

The Ogle-Ridgway Vacuum Filter (Figs. 11 and 12) is another vacuum filter to deal with large quantities of slimes from minerals, and other dewatering purposes. It consists of a series of flat horizontal filtering frames which revolve in a shallow annular tank. From the plan (Fig. 12) it will be seen the tank is divided into three unequal portions by partitions. The first portion is evenly full of slimes pulp kept in a state of agitation by the stirrers shown in elevation. The second portion is full of water. The third and least portion is simply a discharge hopper outlet. On the outer edge of the tank is a runway for the roller carriages which carry the filter frames as seen in the elevation (Fig. 11); this runway rises and falls at the points shown in the plan.

The filter frames are cast-iron shallow boxes, shaped as shown in the plan, Fig. 12, while their section is shown in the elevation. The under face of each is perforated and covered with a filter cloth. The upper face of each is connected to a suction outlet pipe and a compressed air inlet pipe, while to the sides are steel stay-rods connecting the boxes to the steel carrying frames shown in plan and elevation. The suction outlet pipes are all connected to the lower part of the central hollow spindle of the machine, and thence to a vacuum pump. The compressed air inlet pipes are all connected to the upper portion of the hollow central spindle and thence to an air compressor.

There are generally fourteen of these filter frames exactly alike, and all connected to the one central shaft. To this shaft is also attached a drum having wheel teeth geared into a driving worm, by means of which the entire gear is revolved. Thus the whole machine, which at first sight appears complicated and intricate, is seen to be very simple in the details, which are increased in number only to obtain quantity in the shortest time, yet allow a suitable time period for the action of the process.

This action is also a very simple one, being automatic throughout, and exactly similar in each frame for each circuit. Starting at the slimes feed inlet each frame at this point is gliding on the surface of the slimes getting coated; as the suction outlet pipe is open the coating is thorough, and the solution is drawn to the vacuum pump. This continues till

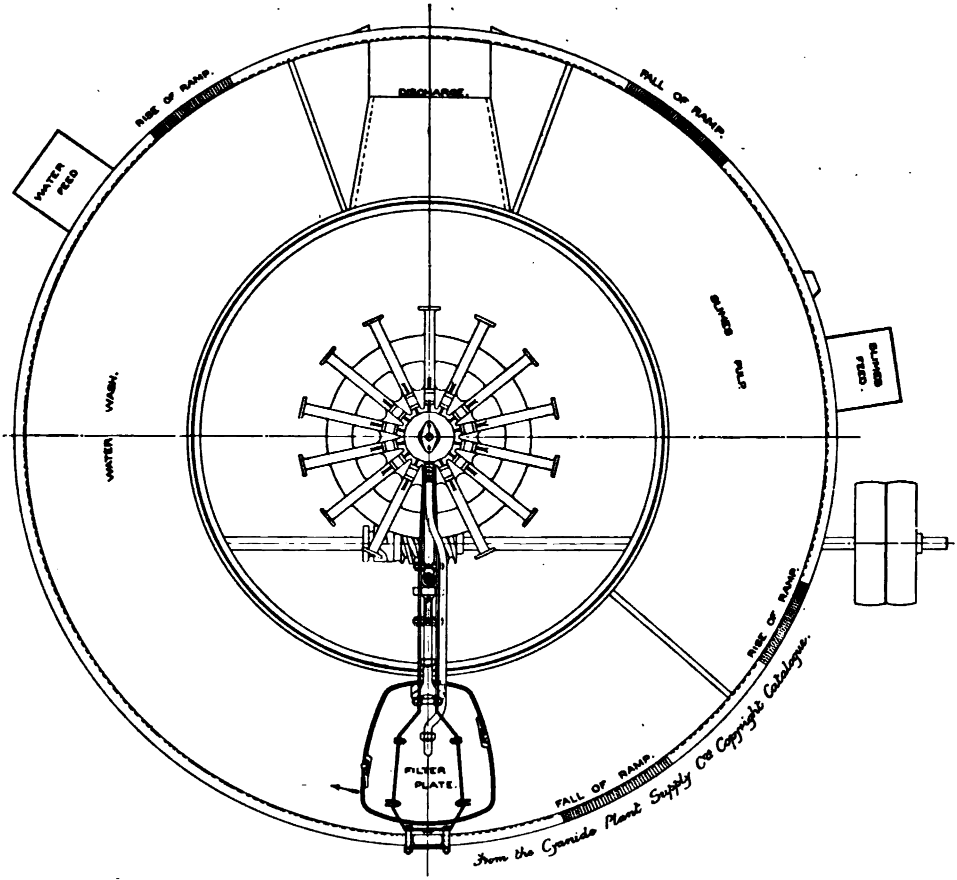

FIG. 12.—OGLE-RIDGWAY VACUUM FILTER (PATENT). PLAN.
(The Cyanide Plant Supply Co.)

each frame reaches near the partition, when the rise in the runway lifts that frame out of the slimes. The suction outlet valve still being open, gives this coating an air-leach, till the fall of the runway takes the frame down to the water of the second portion. Here the partly dried coat is again wetted, and washed free of any solution by the suction. When it has been sufficiently washed the runway again raises the frame for another air dry and thorough dewatering. On reaching the third portion of the tank the suction outlet valve is automatically closed, and the compressed air inlet valve automatically opened. This causes the dewatered coating to fall free of the filter cloth into the discharge hopper and hence away. Each filter cloth is thus in rotation cleared, ready to commence a fresh circuit when again lowered into the slimes portion. The automatic regulation of the valves for the suction outlet is by means of levers and for the compressed air inlet by means of the stop-rollers shown in the elevation.

The result, working with a 13 ft. pan having fourteen filter frames, is to form a quite thin cake in fifteen to thirty seconds in the pulp portion, and thirty seconds to one minute in the water portion. To remove the residual solution, only 16 cwt. to 1 ton of water per ton of dry slime is used, and about 26 to 33 per cent. of moisture is left in the discharge. It absorbs ½ H.P. to rotate the machine, ½ H.P. for the agitators, the vacuum pump and air pulsator, with shafting, &c., take 4 H.P., that is 5 H.P. in all, for the output of 50 tons per day. The working cost of 4d. per ton for separating the gold solutions from the slimes, and delivering the slimes in a "dewatered" state, compares favourably with the 1s. 4d. per ton usual in filter-pressing similar slimes on a corresponding larger scale.

Drying by Absorption.

Some materials otherwise difficult to dry are mixed with inert bodies which have a greater affinity for water. These bodies are usually chosen for their greater facility of being desiccated previous to their mixture with the more sensitive and generally more valuable ingredient. As they must usually be in other respects somewhat similar, the range of choice is very limited. This is absorption by mixture, and this mixing will generally be a tedious and expensive operation if a good dry, even sample is required.

These inert bodies are sometimes abstracted by further processes of manufacture. In any case for efficiency an intimate contact must be obtained, and the drying is a direct absorption which does not reduce the actual amount of moisture but only the relative humidity, although it may facilitate the reduction of the actual moisture.

Yeast is thus sometimes dried by adding an inert, innocuous, sterilised, and vesicular absorbent.

Sawdust, chalk, charcoal, sugar, lime, sand, &c., may be so used for different cases, and owe their efficiency to capillarity arising from their porous nature.

An interesting instance of this same property acting to dry a substance without any assistance from foreign bodies, is seen in the efflorescence of some salts, which will thus gradually give off their water of crystallisation.

Other absorbent bodies, which also owe their action to capillarity, and require to come in contact with the wet body, do not necessarily entail mixing. A typical instance of this is the application of blotting-paper to ink. It is further illustrated by the ordinary use of a sponge, while it is applied mechanically in traversing blankets passing over rollers to dry printed matter, and themselves dried continuously for re-use. (See under Drying-Rooms.) Towels are a domestic instance of the same principle. Then trays of absorbent material are used for drying, and afterwards themselves dried for re-use, as in the manufacture of macaroni.

The air may be dried by absorption of its moisture by deliquescent and other substances which have a strong affinity for water, for instance, quicklime, calcium chloride, or oil of vitriol, and this desiccated air immediately tends to dry the surrounding objects. This property is used in absorbing the damp from enclosed show-cases, and in desiccating substances for analytical purposes by placing them in a desiccator with the desiccant, but not in contact. For instance, Fig. 13 shows the *Hempel desiccator*, made of glass and used for analytical drying. As water vapour has a lower specific gravity than air, the moist air rises and therefore the desiccant is placed in the trough of the lid while the substance to be dried is placed in the lower portion of the glass. The connection and tap allow of the operations being assisted if desired by means of more or less exhaust. The upturned hook deflects the inrushing air when desiccation is complete.

On a larger scale this principle is used for drying night soil by the use of quicklime in an enclosed vessel. Further, it is sometimes assisted and accelerated by placing the absorbent in direct contact with an air current, and made more accessible by admixture with some foreign body such as peat. This enables it to be used for such purposes as desiccating the air for blast furnaces, &c.

In the manufacture of large clay ware, such as lavatory basins, closets, urinals, &c., the preliminary drying of the clay is by absorption. The clay is worked into moulds, which are of plaster of Paris, built up in iron frames. These moulds are themselves thoroughly dried in drying ovens each time before use, and the porosity of the plaster causes it to greedily absorb moisture from the wet clay. This serves the double purpose of removing part of the water of manufacture and leaving the goods much more firm for handling.

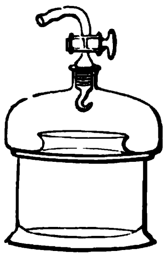

FIG. 13.—HEMPEL DESICCATOR. (J. J. Griffin & Son, Ltd.)

A rise of temperature greatly increases the vapour-carrying capacity of air (see Table VI. and Table VII.). So if warmed air be blown into a room in which the air is laden with moisture, the moisture is greedily absorbed by the fresh, warm air, thus drying the atmosphere of the room by absorption. This is especially useful in evaporating rooms, and other rooms, such as dye-houses, breweries, &c., where water is given off from materials in open or partially enclosed vessels. It is, of course, worked on the plenum process by the air passing through a heater and direct into the room, as in Fig. 49, or distributed to the parts most affected by ducts or distributors similar to Fig. 51. By thus absorbing the steam (or vapour) the humidity is not only lowered, but the whole room and fixings are kept warm and dry, while the goods are saved from the injury which arises from "drops" of condensed vapour. For instance, take a dye-house having ten dye-becks, each about 5 ft. by 4 ft., with their contents at 212° Fahr. There is an active evaporating surface of 200 sq. ft. giving off approximately 92 gals. or 920 lb. of water per hour. Assuming the air of the dye-house is at 62° Fahr., then each cubic foot of air can only contain ·000881 lb. of vapour. Therefore to carry off this vapour a minimum of $\frac{920}{\cdot 000881 \times 60}$ cub. ft. = 17,404 cub. ft. per minute are essential, while in practice at least 25 per cent. more would be requisite.

Drying by Condensation.

Where materials have to be dried which are very sensitive to heat and require handling at low temperatures, it is found necessary to dry the air by condensation.

From Tables VI. and VII. it is apparent that the vapour in a saturated mixture decreases rapidly with the decrease of temperature. Hence if the air be drawn from a room at, say, 62° Fahr., it may contain up to ·000881 lb. of vapour per cubic foot. When this air is cooled down to, say, 22° Fahr., it can only carry ·000202 lb. per cubic foot at the utmost, therefore it must condense any it has beyond that amount, that is, any amount up to ·000881 – ·000202 = ·000679 lb. per cubic foot. The air at 22° Fahr. is saturated, but if it be led back into the room at 62° Fahr. it will become heated nearly or quite up to the 62° Fahr., and its vapour capacity will again be ·000881 lb. per cubic foot: as it is only carrying ·000202 lb. per cubic foot, it can absorb up to ·000679 lb. per cubic foot. If the cooling process be repeated to 22° Fahr. the condensation would again occur.

At first sight it may appear as though here was an instance of drying by evaporation without heat. But a little consideration removes this idea. At the commencement the room and its contents were at 62° Fahr., but when the air was returned it was at 22° Fahr. Either the returned air will remain at 22° Fahr., or the room and its contents will give up sufficient heat to raise it, whether to 62° Fahr. or less will depend on their relative bulk and heat capacities; or if this heat be not replaced by some independent source, the room and its contents will be reduced in temperature exactly in proportion to the heat taken up by the cold current.

This vapour abstracting and heat abstracting is exactly what occurs in cold storage in ships and elsewhere. When carried to lower degrees, it becomes refrigerating, or ice is made.

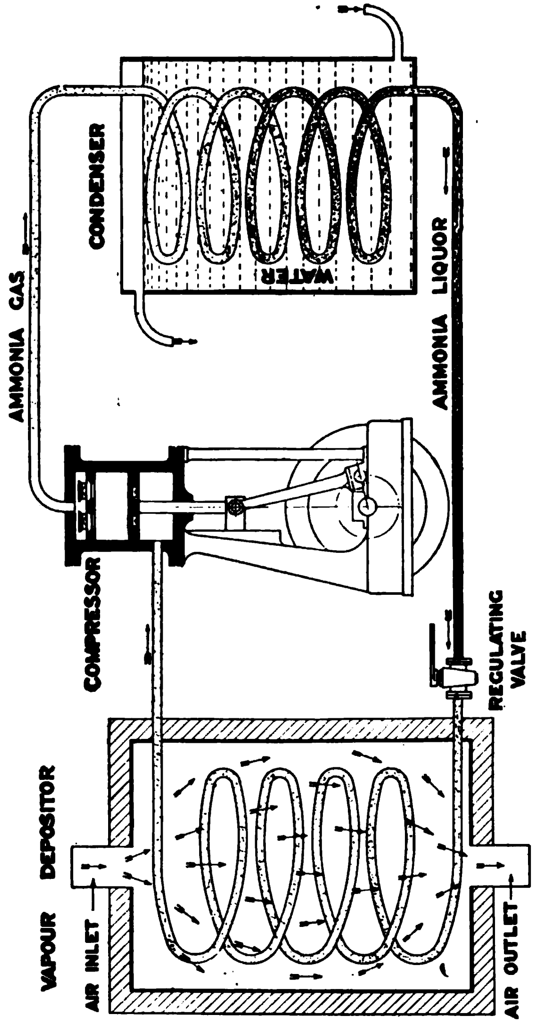

FIG. 14.—NORMAIR VAPOUR DEPOSITOR. DIAGRAM OF SYSTEM. (Pulsometer Engineering Co., Ltd.)

The cooling of the abstracted air is essentially the reverse operation to that obtaining in the storage or drying-room.

It has been known for many years that compressing air or gas causes a considerable accession of temperature. If, while the gas is under the increased pressure, the heat is eliminated and the temperature lowered, the gas becomes a liquid. This liquid being relieved of the pressure returns to the gaseous condition. In order to vaporise or gasify, heat is necessary, and the gas greedily absorbs heat from all surroundings, causing a rapid and considerable fall of temperature.

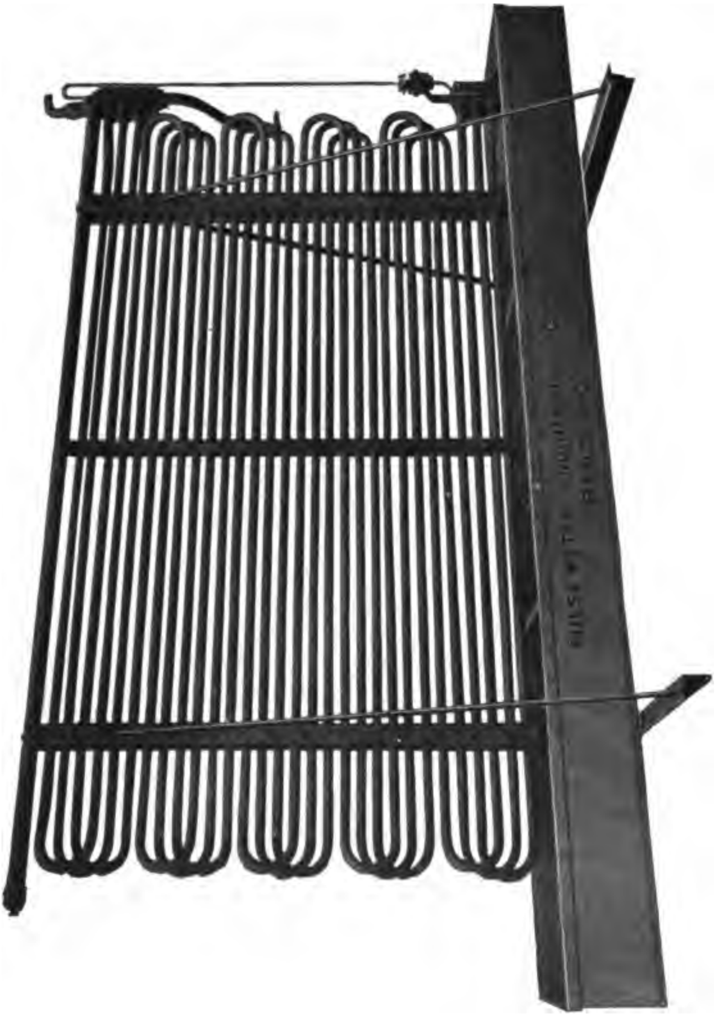

FIG. 15.—NORMAIR REFRIGERATING COILS.
(Pulsometer Engineering Co., Ltd.)

Use has been made of ether, air, carbonic anhydride, anhydrous ammonia, and other gases in this manner, and Fig. 14 gives a clear diagrammatic illustration of the procedure as used in the *Normair Vapour Depositor.* The gas is brought under pressure in the compressor cylinder and forced into the pipe to the condenser. Here a continuous stream of water eliminates its surplus heat, and the ammonia leaves the condenser in a liquid state. Passing through the coils of pipes in the depositor the ammonia expands and absorbs heat to vaporise, thus cooling the pipes and surroundings to the degree arranged. This vapour returns to the compressor cylinder and thus completes the circuit. While Fig. 14 shows diagrammatically the process throughout the ammonia circuit, Fig. 15 shows the form which the coils actually take in the depositing chamber. The vapour laden air coming into contact with the heat-absorbing coils rapidly loses its heat, and the vapour gives up its latent heat. Thus the vapour is condensed and deposited upon the coils, thence falling into the tank below. If the temperature be below 32° Fahr., some of the vapour would, of course, become attached to the coils and need washing off by a brine shower. In actual use, however, the minimum temperature is usually 52° Fahr., in which case no ice is formed and the vapour is deposited as water.

The air, cooled by its contact with the coils, may be returned to the drying space in its cooled state, or may be heated before returning to the drying space. When the air is returned cooled it absorbs the heat from the drying space and its contents, and thus increases its own vapour capacity at their expense. But if the air on leaving the cooler is heated to the same temperature as the drying space, then its vapour capacity is increased without diminishing the temperature of the drying space. Both these courses are followed in actual drying operations, the choice depending on the nature of the material and its thermal characteristics.

The efficacy of this method of drying is very great, but its efficiency and economy are entirely dependent on skilful adaptation of the several processes and a complete harmony of the various parts of the plant. The outstanding advantage is the provision of a pure dry air supply to the drying space, free from contamination and independent of all local conditions of temperature, humidity, or pressure.

CHAPTER III

MECHANICAL DRYING

Mechanical Drying.—When Applied—Methods - - - 30
Drying by Pressure.—Direct Pressure—Peat Unwatering—Westaway Patent Peat Press—Higginbottom-Lennox Patent Water Extractor for Peat—Filter Presses—When Used—Construction—Filter Press with Hydraulic Cylinder—Filter Press Plates—Results—Filter Press Plant - 30-36
Drying by Centrifugal Force.—Centrifugal Force—Applications—Centrifugal Fans—Centrifugal Pumps—Centrifugal Screens—Centrifugal Separators—Centrifugal Disintegrators—Hydro-Extractors—Centrifugal Dryers—Construction of Centrifugals and Hydro-Extractors—Uses—Broadbent Suspended Centrifugal—Electric Drive—Laidlaw Hydro-Extractor—Laidlaw Patent Buffer and Bearing—Centrifugal Plant—Self-Discharging Centrifugals—Water Motor Drive—Interlocking Gear—Centrifugal Outputs—Hydroed Results—Vertical Whizzer—Robinson's Ventilated Whizzer—Construction—Use - - - - - - 36-46

MECHANICAL methods of drying are efficient when the water forms a large proportion of the weight, where the association of the water with the solid particles is comparatively small, and when the solid material is openly porous in structure. They are generally suitable when the condition is "soaked" or "wet," seldom when "damp," and in most cases leave the material "damp" or "moist." As positive direct methods they can be regulated, accelerated, and adjusted to meet the needs of the substance. Two methods in which purely mechanical means are used for drying are:—

(*a*.) Pressure, as in direct presses and filter presses.
(*b*.) Centrifugal force, as in hydro-extractors and centrifugals.

(*a*.) **Drying by Pressure.**—There are but few cases where direct mechanical pressure is utilised in removing water from the substance of articles, although direct pressure rolls and presses are common to extract liquors, oils, &c. For removing some of the surplus water (unwatering) from peat, pressure has

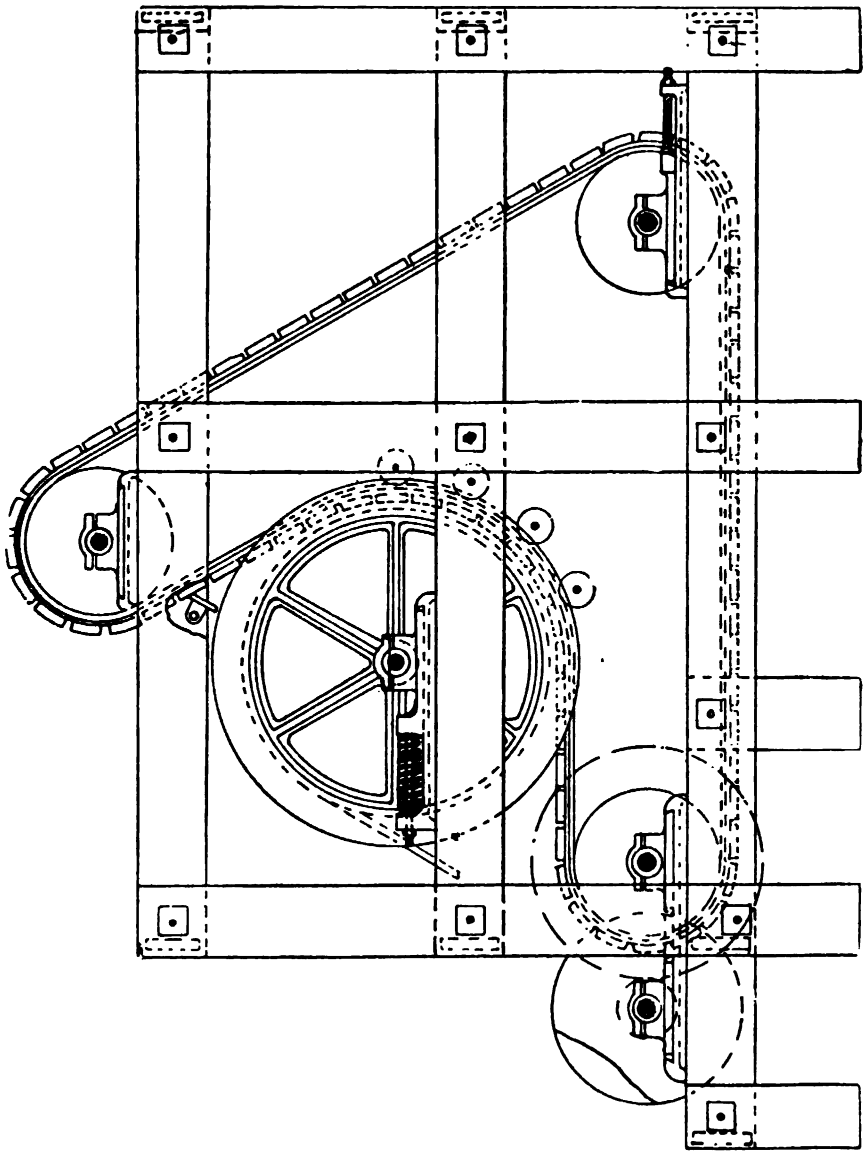

FIG. 16.—HIGGINBOTTOM-LENNOX (PATENT) WATER EXTRACTOR FOR PEAT. (A. B. Lennox.)

been applied in several ways, notably by the Westaway and the Higginbottom-Lennox patent squeezers.

Westaway provided a hollow frame of two sides connected at the corners by struts and girders. Between the inner sides of the frame and arranged across same are fixed two sets of adjustable pressure rollers with an intervening space between, which space is wider at the top than the bottom. Above and below these pressure rollers are mounted four drums over which work two endless bands, one of the bands passing around each set of the drums and pressure rollers. These bands are independently driven by gearing, and as they feed the material (peat) downwards they also compress or squeeze it.

An even simpler form is the *Higginbottom-Lennox* (*Patent*) *Squeezer*, which is illustrated in Fig. 16. This has only one continuous or endless band, and squeezes the peat directly against the periphery of the large central drum shown. This central drum can be adjusted to suit the supply and the band by means of screws on the plummer blocks. Having only one band allows of a direct simple drive, and at one drum only, as the remaining drums are merely for guides and adjustment purposes. The whole can readily be fixed up on a stout timber framework and conveniently transported to any part of the bog where required.

But there are numerous instances where pressure, either as steam or compressed air, serves to remove the water from thick liquids by separating the solid components from the attached water, as in filter presses.

Filter Presses are used for semi-solids which contain a large proportion of water, say 80 per cent., or are "soaked," and leaves them "damp," generally about 20 per cent. moisture. This is exactly what is required in sewage sludge. In other cases they are used to reduce the moisture to this degree ready for the further drying by evaporation. They are efficient for removing a large bulk of water from granular substances in a state of thick mud.

There are many types and various modifications to suit particular substances and the ideas of different makers. Essentially they consist of—

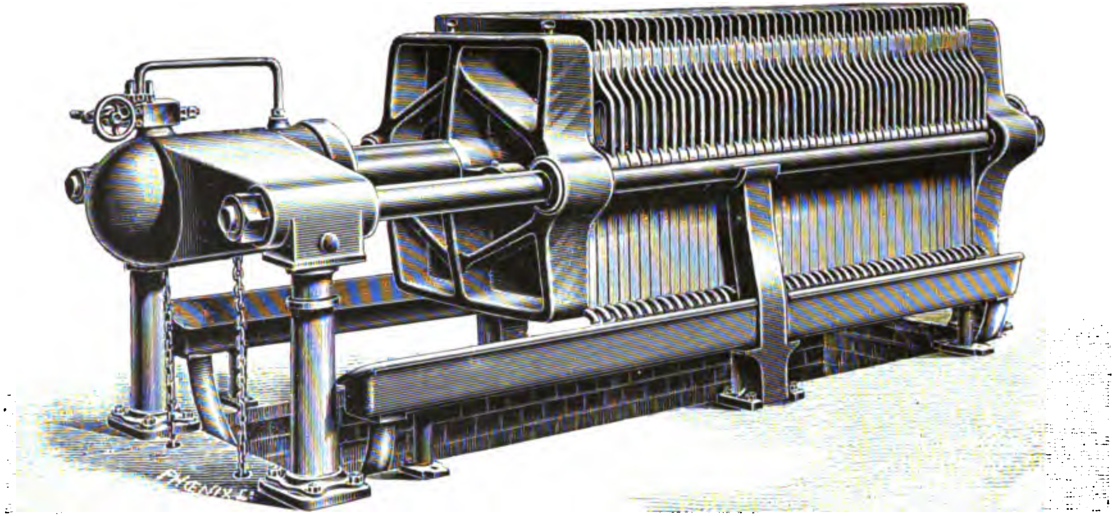

FIG. 17.—FILTER PRESS COMPLETE.
(Manlove, Alliott, & Co., Ltd.)

1. A number of flat sections or chambers formed of iron plates covered with filtering cloths, and supported in
2. A frame of considerable strength, generally horizontal.
3. An adjustable crosshead with means of applying pressure to the sections.

The chambers, which vary in number from four upwards to fifty, are made of various shapes, generally round or square. They have usually separate outlet cocks to each chamber, and are made self-emptying, while the washing or steaming arrangement can be made reversible.

The iron plates are serrated and corrugated in different designs, and the cloths chosen to suit the particular product.

The frame generally consists of two stout bars with supporting legs, and is so constructed as to facilitate the removal of the chambers. The crosshead and tightening should admit of quick removal, and the pressure can be applied by screw, air cylinder, or hydraulic ram as desired.

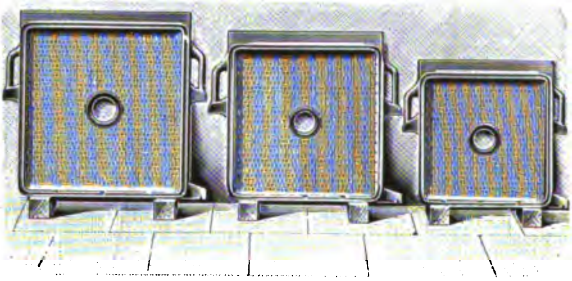

FIG. 18A.—FILTER PRESS PLATES. SQUARE.
(Manlove, Alliott, & Co., Ltd.)

The *Filter Press* (Fig. 17) has square plates similar to Fig. 18A, which are pressed into position by a hydraulic cylinder with a return motion by counterbalance weights not shown, but the chain of which can be seen. The massive tie-bars and cross-heads are well shown, also the separate outlets from each chamber into the common liquor trough in the pit. Figs. 18A and 18B show typical forms of the *Plates* both round and square, as adapted for different materials and sizes of presses.

Filter presses are used in dealing with the precipitated sludge from the tanks of sewage farms. This sludge has about 90 per cent. water, and is pumped into the chambers of the press, about 110 to 140 lb. pressure per square inch is applied, thus removing 80 per cent. of the water, and leaving comparatively dry ("moist") cakes of 50 per cent. solid matter. This most objectionable sludge is thus made into cakes convenient for handling and transport, also practically free from smell.

At the gold mines filter presses are sometimes used for removing the water from the precipitates after leaching, and for extracting the solid matter from the slimes. It is found to save time and water as compared with decantation, but the cost of working is too high for low grade ores. They use compressed air at 30 to 60 lb. per square inch. A charge of 3 tons takes about two hours, fed by pumps or montejus, and the air of the montejus accelerates the cyaniding process. Another purpose is in concentrating the precipitated pigments at colour works, and similar operations at chemical works. Grease is also extracted from magma by specially arranged filter presses.

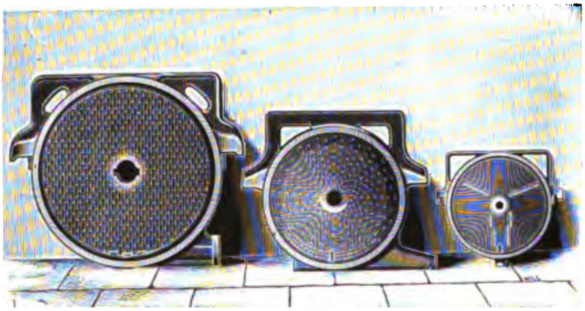

FIG. 18B.—FILTER PRESS PLATES. ROUND.
(Manlove, Alliott, & Co., Ltd.)

In sugar manufacture filter presses are used in dealing with the lime scum of beet sugar. This is delivered into the collecting vats with about 52 per cent. moisture, and is then generally fed to the filter press by two montejus, which work alternately. The pressure of the montejus also compresses the lime in the filter when steam is passed through to dissolve any remaining saccharine matter before removing the residue. The filter cloths are frequently dried in the hydro-extractors used in other processes at sugar works.

Fig. 19 shows a typical *Filter Press Plant* as adapted for handling gold slimes expeditiously. The slimes in the monteju B are raised into the filter press C by the steam from the boiler D. The pressed cakes fall into the hopper, under which a truck can be run to receive them. Such a plant does about ten charges a day of twenty-four hours of wet pressed cakes which contain (by weight) about 30 per cent. moisture. The weight of the charge depending, of course, on the size of the filter press.

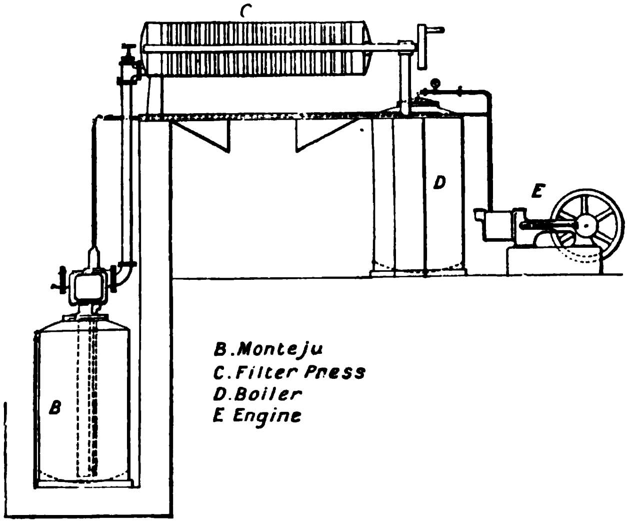

FIG. 19.—FILTER PRESS PLANT.
(The Cyanide Plant Supply Co., Ltd.)

(*b*.) **Drying by Centrifugal Force.**—As a body when in motion will continue to move in a straight line unless acted on by some external cause, every part of a rotating body has a tendency to detach itself and fly off at a tangent to its centre of rotation, and any body caused to revolve by a rotating body has the same tendency, which property is called centrifugal force. Hence any substance on or in a rotating body is thrown off at a tangent unless means are provided to retain it. This principle is utilised in several types of machines, for instance propelling the air by *centrifugal fans*, lifting and forcing water in *centrifugal pumps*, forcing powders against the meshes in *centrifugal screens*, spreading the powders in *pneumatic centrifugal separators*, crushing granular materials against the insides of *centrifugal disintegrators*.

Going a step further, it is used to separate two intimately mixed substances by putting obstacles which retain the one while the other is allowed to fly off. For instance, by retaining wet clothes in a rotating basket while the water is permitted to take its natural course, and thus be thrown off, leaving the clothes comparatively dry, as in hydro-extractors and other centrifugal drying machines.

A *Centrifugal Drying Machine* as now made consists essentially of:—

1. A circular basket rotated on
2. A vertical central shaft and enclosed by
3. An outer stationary casing.

The circular basket is drum-shaped, having an open top to insert the material, and sometimes a valve in the bottom to form an outlet for dried powders or crystals. The periphery is perforated with various sized holes or is covered with wire meshing. The materials used in the construction of the basket are steel plates, bronze, copper, aluminium, silver, china, &c., to suit the occasion. Those dealing with acids are usually lined with lead, though sometimes hard rubber or enamel is used. When handling explosives it is found necessary to close the top aperture. In all cases the symmetry and balancing of the basket are of great importance, while the material to be dried should be placed as evenly as possible.

The central vertical shaft presents the critical feature of all centrifugals. It may be suspended from above (as in Weston and Hepworth types) when it is over-driven, or rest on a footstep (as in Fesca type) when it is under-driven. In either case the shaft, although running at a high speed, cannot be held in rigid bearings but must have convenience for adjusting itself to a true centre, or the vibration would rapidly wreck the machine at great risk to the worker. Both types need great consideration of the lubrication, and the methods devised by the makers are very ingenious. The drive may be by belt, friction pulleys, or direct by steam engine, electric motor, or Pelton water wheel, and in all cases should be ample to quickly obtain the speed, but when once the momentum is obtained but a small power is required in well-balanced machines. Although the centrifugal force increases continuously as does the speed, it has been proved by actual trial that the results in drying are not improved by exceeding 1,500 revolutions per minute in a 24-in. machine, to a proportionate reduction in the larger machines, and in use it is well to bear in mind that if the load is increased the speed should be diminished. The direct drive by small independent or attached motive power has the advantages of ensuring a more regular speed, and of allowing the work to continue when the main power is stopped. The outer stationary casing is generally of light steel plate; it serves as a collector for the water and as a guard for the rotating basket.

When the basket is designed to suit laundries and the textile trades, these machines are generally called *Hydro-Extractors*, which, considering their purpose, is certainly a more distinctive term than Centrifugals, which may be equally applied to machines performing many other duties. Besides being used in laundries to extract the water left in washed clothes, this type of machine is usual in the dye-houses and finishing rooms of textile factories for wool, cotton yarns, cops, piece goods, &c.

Called *Centrifugal* machines, they are used in sugar factories and refineries, in chemical works, gun-cotton factories, and starch factories, where the basket, while retaining the general drum-like form, assumes numerous modifications in detail, fineness of perforation, &c., to suit the different requirements.

The *Broadbent Centrifugal* (Fig. 20) is of the under-driven type, by direct self-contained engine. The section shows the characteristic suspension by rods in exterior columns on a cast-iron base plate. This takes up the strains and minimises the vibration attendant on high speeds. It also simplifies the bearings of the main spindle, as this can be rigid with respect to the outer frame casing, since the whole casing is suspended and takes the strains in harmony and not at the bearings only. The form of the outer casing and basket are clearly

shown, together with the valve and shoot for bottom discharge of granular substances.

The *Broadbent Electrically Driven Hydro-Extractor* is represented in Fig. 21. As will be seen in the section, the basket is mounted on a vertical spindle supported above and below in ball bearings. The armature is built upon a sleeve surrounding the vertical spindle, and the field magnets are built into the framework of the machine. The whole is supported by four bolts with cup-and-ball joints, as shown in the figure. This ensures that the basket will run concentrically with the frame, and renders heavy foundations unnecessary, as any out-of-balance effects due to unequal distribution of the materials in the revolving basket merely cause the whole frame to swing slightly. The normal speed of the basket is 900 revolutions per minute. To avoid the use of a heavy starter an automatic friction clutch is interposed between the motor and the drum. The motor armature is mounted on a sleeve which can revolve round the central spindle, and leather-covered friction shoes attached to this sleeve fly out by centrifugal force and gradually grip an outer ring attached to the central spindle and the drum. The weight of the shoes is adjusted so that, at normal speed, the friction is exactly sufficient to transmit the normal power of the motor. The motor runs up to full speed almost instantly, but the drum is brought up to speed gradually. Starting up is therefore quite automatic, and the current taken by the motor can never be very excessive. The motor, which can be either for continuous or alternating current, is well protected from water. Various sizes, from 26 in. diameter to 72 in. diameter, can be obtained. All machines are fitted with a hand brake for bringing the drum quickly to rest.

The *Laidlaw Hydro-Extractor* (Fig. 22) is of the over-driven type by belt throughout, but may be by water or electricity. The section illustrates the self-balancing and conical bearing with the rigid outer casing and overhung head frame. As an hydro-extractor for clothes it has no bottom discharge, but ample provision for the water in the trough of the outer casing. The belt drive gives great adaptability in adjustment, and allows of a slower speed from the main drive.

The latest form of *bearing* for this overhung type is shown in Fig. 23. The conical form of the buffer greatly assists the self-adjustment, and tends to control the oscillation of the centrifugal. The ball bearings have four circumferential rows of balls fitted in the cone C. They only require to be greased occasionally, not lubricated with oil. Lubrication has been a very sore point with all centrifugals as with other high speed machines, and the removal of this difficulty is of great importance to users.

In applying for quotations or in ordering centrifugals of any kind, it is best to state clearly the material and purpose it is for, also the quantity desired to be dealt with at one time of filling. To obtain the necessary capacity for the quantity, it is most convenient to fill any box or basket with the quantity of the actual article, and measure up the cubical contents.

In Fig. 24 there is a complete *plant of Laidlaw Centrifugals* for producing white sugars, by separating (or drying) them from their syrups. At the same time it gives a lucid section of a *Self-Discharging Centrifugal (Patent)*, especially suitable for raw sugars before refining. In this type the material falls on to a spreading cone which throws it rapidly to the sides, where the solid particles remain held by centrifugal force so long as the machine runs. When the machine stops, the solid particles fall automatically into the receiving hopper below deprived of their surplus liquor.

Taking the plant *seriatim* from the feed, by truck or otherwise from the crystallisers into the receiving hopper, the wet sugar is elevated by a tubular elevator into the storage hopper, whence it falls into the preliminary centrifugal to remove the thick molasses. This first *centrifugal* is of the *self-discharging* kind described above, and will handle 3 to 5 tons of wet sugar per hour. From this large centrifugal the sugar falls into the pug mill, where it is sprayed and mixed with the thin molasses from the small centrifugals. The second tubular elevator delivers the mixture into the usual mixers and purgers above a battery of small centrifugals. The centrifugals are of the over-driven type by independent water motors, and dry the sugar for the second time, thus keeping the two liquors apart while securing a more thorough purging and drying. The drive can be by belt or direct steam where advisable. The framework and structural work is of steel channels and bars

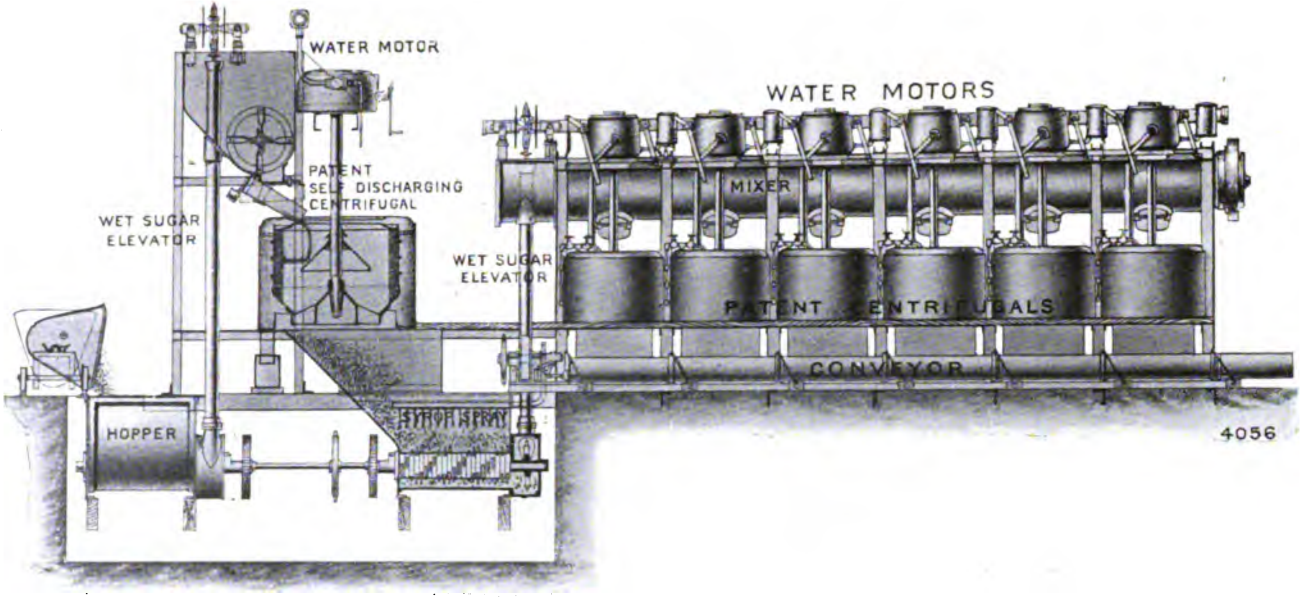

FIG. 24.—LAIDLAW CENTRIFUGAL PLANT. GENERAL VIEW, PART SECTION.
(Watson, Laidlaw, & Co., Ltd.)

throughout, suitable for any climate, while ready for immediate erection on delivery.

A water driving gear for a centrifugal is illustrated by the cut-away section, Fig 25, which, together with the interlocking gear shown in elevations, Figs. 26 and 27, forms a very compact, economical, and readily controllable driving arrangement for twin centrifugals, allowing of alternate or combined running.

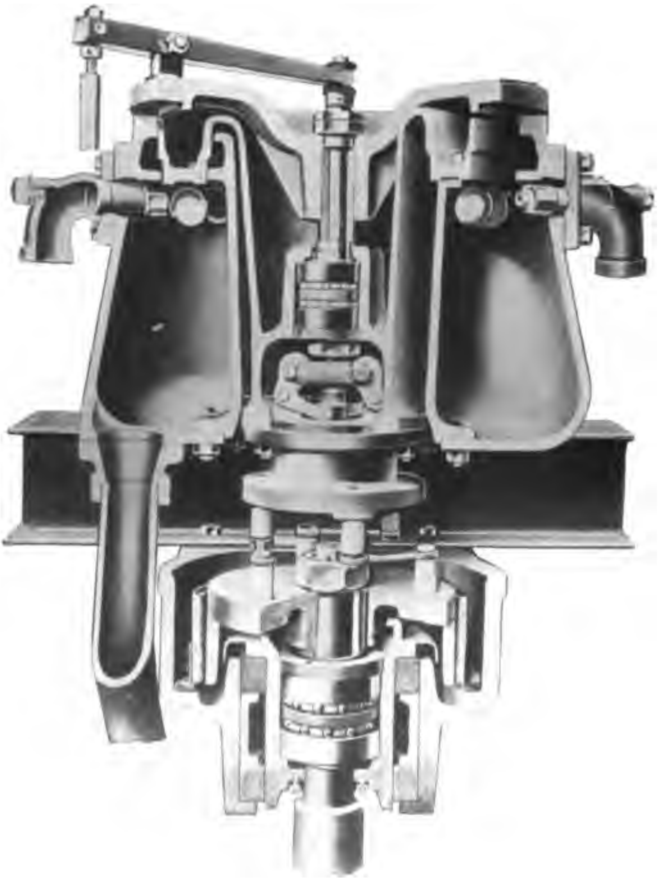

FIG. 25.—WATER DRIVING GEAR FOR A CENTRIFUGAL.
(Pott, Cassells, & Williamson.)

As will be seen from Figs. 25 and 26, the water motor is fixed above the framing, and drives the centrifugal basket, which is below it, through an elastic coupling, the basket being fixed at the lower end of a vertical spindle which has only one bearing. The water motor, which is of the Pelton-wheel type, rotates on a ball bearing around a fixed spindle. The body of the motor (Fig. 25) is carried upwards and is turned over the casing with a double flange, upon which the buckets are mounted. The flanges prevent the water spray from getting over the top. The spent water is thus compelled to flow through the return-water pipe back to the water tank which supplies the pump for driving the machine.

To the bottom of the water-motor boss there is bolted a driving flange, upon the upper side of which there are mounted the governor balls in an oil-tight cavity, partly filled with lubricating oil, below the upper ball bearing. The governor balls are held in the off position by the governor springs. The arms are coupled by a rod passing up the hollow spindle in the centre of the motor to a lever working on a fulcrum placed on the top of the motor-case cover; a swivelling cross-head, through which passes the governor rod, is fitted at the outer short end of the lever. When the machine attains full speed, the governor spindle is moved upwards and the governor rod is pressed downwards, when it acts on a trigger, cutting off the water from one of the two jets—the accelerating jet—which can be seen in Fig. 25, leaving the smaller, maintaining jet on the opposite side in operation.

Underneath the beams is the elastic bearing carrying the upper end of the basket spindle. Into this are fitted india-rubber buffer rings separated from each other by a loose ⊔-shaped cast-iron ring (Fig. 25). Both top and bottom buffers, therefore, support the weight of the centrifugal basket. This patented arrangement of buffers gives great resilience and perfect steadiness to the machine when running with a balanced or unbalanced load, and as the buffers are separated by the loose ⊔-shaped cast-iron ring, any wear on the bottom buffer is compensated for. The ball-bearing housing fits inside the indiarubber buffers, and contains the compound ball bearing. To permit of the oscillation of the centrifugal spindle and basket, the water wheel above, which does not oscillate, is connected to the brake pulley on the top of the centrifugal spindle by three links, the eyes of which are slipped over the points of the driving pins into a groove. The links thus form a strong flexible coupling, both simple and effective. The motor or the centrifugal can be detached, when desired, by slipping off the links.

The brake band is supported by an angle iron resting on a flange in the suspending bracket, there being thus no possibility of the brake drooping unequally. When the brake is off there is an equal space all round between the brake band and the brake pulley.

The interlocking gear is shown in Figs. 26 and 27. This works as follows:—When the accelerating lever is pushed over from right to left, it opens the accelerating water valve, which is on the left hand of the motor case, and, by means of a short connecting link, it opens at the same time the maintaining water valve, which is on the right hand of the motor case, and so causes the jets shown in the section, Fig. 25, on both sides of the water wheel to act on the water-wheel cups. When the hand is removed from the accelerating lever, a spring is prevented from cutting off the accelerating water valve by the point of a small round horizontal trigger rod pressing against the jaw of a trigger-rod bracket, the trigger rod being pulled up into the horizontal position by the governor springs contracting when the machine was stopped the previous time. When the machine attains full speed, the governor, as above stated, pushes down the governor rod, which, in turn, pushes down the trigger rod, when the spring on the accelerating lever will shut off the accelerating water valve. The maintaining water valve is not affected by this operation, and remains open until it is desired to stop the machine, when it is shut by hand and the brake applied.

TABLE I.—CENTRIFUGAL OUTPUTS.

The Weston type is largely used in sugar factories and refineries. The table below gives data of good modern practice in its use: the power given is that for getting up the momentum, and is reduced to about one-third when running.

PLATE IV.—Drying Machinery and Practice

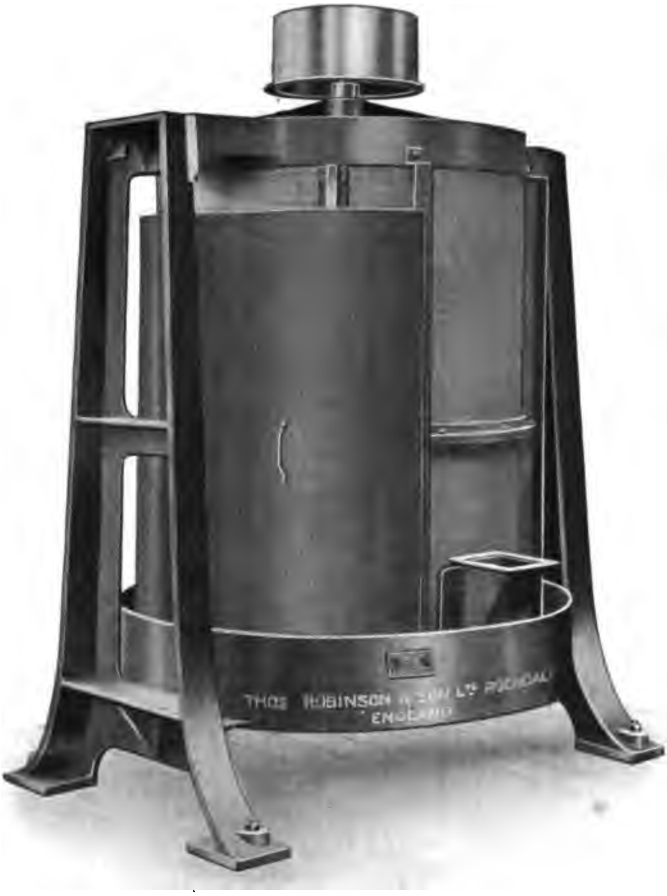

FIG. 28.—VERTICAL WHIZZER. GENERAL VIEW.
(T. Robinson & Son, Ltd.)

[*To face page* 45.

Diameter of Basket in inches.	Speed of Basket in Revolutions per Minute.	Indicated H.P. required for One Machine	Basket Capacity in Cubic Feet, net.	Approximate Output of each Machine in Lb. per Hour.				
				Qualities of Sugar.				
				In Factory.		In Refinery.		
Inches.	Revs.	I.H.P.	Cub. Ft.	1st.	2nd.	1st.	2nd.	3rd.
30	1,200	4	4	2,100	616	4,040	1,335	1,010
36	1,000	5	5	2,350	770	4,480	1,478	1,120
42	850	6·75	7·8	2,800	1,200	5,380	1,775	1,345
48	750	8	10·3	3,750	1,586	7,170	2,366	1,792
54	700	9	11·9	4,000	1,832	7,620	2,540	1,905
60	600	10	13·4	4,200	2,063	8,070	2,690	2,015

TABLE II.—HYDROED RESULTS.

Comparison of residual moisture in wet cloth when twisted, when pressed, and when hydroed in a 26-in. machine running at 500 to 600 revolutions.

	Flannel.	Calico.	Silk.	Linen.
When twisted - - -	2·00	1·000	·95	·75
„ pressed - - -	1·00	·6	·5	·40
„ hydroed - -	·60	·35	·3	·25

Centrifugal force has been further developed for drying by a combination of the centrifugal action and ventilation. This machine, as illustrated in Fig. 28 by a general view, is more clearly shown in the vertical and horizontal sections of Figs. 29A and 29B respectively, while Fig. 29C is the plan. It is called a *Vertical Whizzer*, and is used to "unwater" and partially dry corn as it leaves the washer and stoner. The corn being fed into the inlet spout at the bottom of the whizzer is at once met by a series of lifters. These lifters are of angle iron section shaped to lift but not abrade the corn. They are travelling at a velocity of 3,000 ft. per minute, and carry the corn round the periphery of the machine in an upward direction to the delivery spout at the top. During this high speed transit the water is thrown off the corn. Thus a more complete action is obtained than in a hydro-extractor (or centrifugal) of the basket type, besides the continuous automatic feed and delivery.

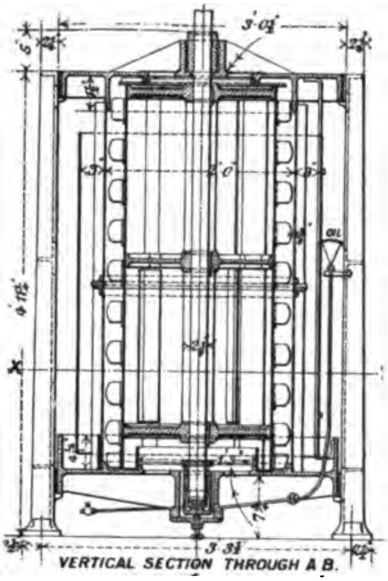

FIG. 29A.—VERTICAL WHIZZER.
(T. Robinson & Son, Ltd.)

The mechanism is very simple: the lifters are attached to a skeleton drum, consisting of a vertical steel shaft with cast-iron spider arms carefully balanced to prevent vibration. The drum is supported by a footstep bearing, and is belt driven by pulley at the top, and is the only moving part of the machine. Outside of and concentric with the drum and lifters is a galvanised steel perforated casing in removable sections through which the water is expelled. A splash guard or cover of sheet steel is around the casing to conduct the water into the heavy cast-iron base ring. The whole is self-contained in a substantial framework of cast iron to which are attached the lubrication pipes for the footstep bearing.

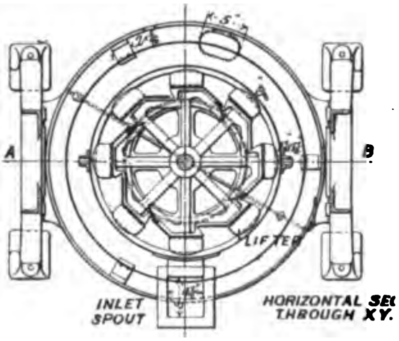

FIG. 29B.—VERTICAL WHIZZER.
(T. Robinson & Son, Ltd.

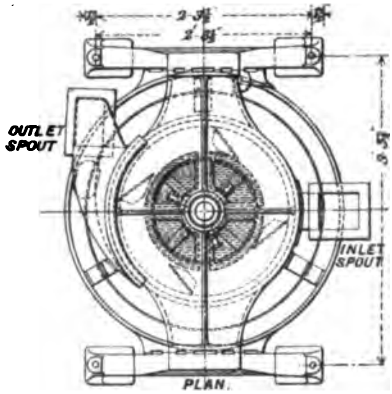

FIG. 29C.—VERTICAL WHIZZER.
(T. Robinson & Son, Ltd.)

CHAPTER IV

DRYING BY EVAPORATION

Evaporation —Saturation—Elastic Force—Factors of Evaporation—Cost—Wet Material—Dried Product—Scheme - - - - - 47-49

Heat.—Internal Work—External Work—Latent Heat—Sensible Heat—Ice—Latent Heat of Water—Water—Latent Heat of Vapour—Critical Temperatures—Heat Transmission—Conduction—Convection—Radiation—Specific Heat Table—Expansion by Heat—Coefficient of Expansion—Thermal Capacities of Air — Measurement of Heat — Calorimeters — Thermometers — Pyrometers — Callender Patent Recorder — Whipple Patent Temperature Indicator — Fuel Values — Calorific Value and Evaporative Power of Fuels - - - - - - 49-56

Air.—The Atmosphere—Air as a Drying Medium—Heat Vehicle—Vapour Vehicle—Attenuated Vapour Ballast—Weight of Air—Boiling Point—Elastic Force — Air Pressure — Diagram of Equivalents — Inlets and Outlets of Drying Rooms—Expansibility of Air—Effects in Drying—Table of Properties of Air, Aqueous Vapour, and Saturated Mixtures—Air Currents—Anemometers—Robinson's Anemometer—Portable Air Meters—Biram's Air Meter—Syphon Draft Gauge - - 56-67

Vapour.—Gas—Aqueous Vapour—Vaporisation—Ebullition—Expansibility—Elastic Force—Weight—Effects of Temperature upon the Vapour Capacity of Air—Pressure—Effect on Vapour Capacity in Air and *in Vacuo*—Vapour Weights in Grain per Cubic Foot—Vapour Indications and Measurement—Hygrometer Tables—Vapour Polymeter—Hygroscopes - - - - - - - - - 67-74

Evaporation.—Wherever there is water, from its free surface arises vapour. It occurs slowly even while the water is in the solid form as ice, and increases in speed with every increase of temperature. This evaporation proceeds whatever the pressure of the atmosphere about it may be; although an increased atmospheric pressure decreases the speed, it does not lessen the final amount per cubic foot of space. The amount of evaporation is only limited by the fact that a certain space can only contain a fixed weight of aqueous vapour at any given temperature. As the vapour arises it forms an atmosphere of its own quite independent of the presence or absence of any air. When this aqueous atmosphere has attained a certain density for each temperature, it is said to be *saturated*, and its own elastic pressure prevents any further evaporation until the density is lessened by the removal of some of the vapour. In an open atmosphere the natural tendency of this aqueous vapour to diffuse like any other gas prevents any particular space becoming fully saturated, hence under natural circumstances *saturation* is seldom reached.

This diffusion is comparatively slow at low temperatures, but as the temperature rises the *elastic force* increases in greater degree (thus at 12° Fahr. it is equal to a pressure of ·074 in. of mercury, at 32° Fahr. it is ·181 in., at 52° Fahr. it is ·388 in., in other words a rise of 20° Fahr. increases the elastic force 2·4 times, and 40° Fahr. increases it 5·2 times) and the diffusion increases in speed proportionately to the augmented elastic force. From the above it becomes at once apparent that: (1) the amount of free surface, (2) the amount of heat, (3) the pressure of the atmosphere, and (4) the diffusion of the aqueous vapour, are all factors in regulating the possible speed of evaporation or drying by evaporation. Although it is the combination of these that regulates the speed of drying, it will be best to consider each separately. There are other factors which govern the desirable speed of drying, for instance, the physical and chemical nature of the material to be dried, but this is an aspect not under consideration at the moment, although one which essentially is of primary importance in all practical drying. Again, the drying has to be considered in regard to *cost*, and this often leads to a compromise, as the most efficient mechanically may not be the financially economical.

Thus it becomes necessary to carefully consider the *wet material* and the *dried product* desired from every aspect, especially as to how it is affected by heat, by vapour, and by the air. So it is proposed to take a general view of these three factors in their relation to drying operations. Then to consider the application of the heat to drying, the removal of the vapour arising from drying, and the handling of the wet material and the dried product preparatory to and during the drying. Following which it is proposed to describe and illustrate the installations on various systems for practical drying of sundry wet materials to obtain diverse dry products, the consideration of the material naturally arising in connection with the differing arrangements and applications of the several methods.

Heat.

The researches of Davy, Rumford, Joule, and others have fully demonstrated the dynamical theory of heat. Briefly stated, this theory is that heat is a form of energy developed as the relative motion among the molecules or particles of the heated body. This energy or motion being capable of transfer from one body to another, and thus, while generated in the one body, may heat or cause molecular motion in one or more other bodies. Some of this transferred heat (or thermal energy) is used as *internal work* in amplifying the oscillations by which an increase of volume is produced, or in completely altering the relative positions of the molecules by which a change of state is effected, or as *external work* in overcoming the pressure of the atmosphere. The heat thus used does not affect the apparent heat or temperature of the body to which it is transferred, and hence it is called hidden or *latent heat*. Whereas the portion of heat which causes a rise of temperature is apparent or *sensible heat*, and can be gauged by a *thermometer*.

For instance, *ice* at 0° Fahr. rises steadily in temperature as heat units are absorbed till it reaches 32° Fahr., when at 29·921 lb. pressure the temperature rises no more, however many heat units are supplied, till it assumes the liquid form as water at 32° Fahr. The amount of heat units absorbed during the interval is the latent heat necessary to produce the internal work of conversion, and it is found that every pound of ice requires 143 B.Th.U. to convert it to water at the same temperature. This is called the *latent heat of water*. Still adding heat to the water at 32° Fahr., it steadily rises in temperature till it reaches 212° Fahr., at 29·921 in. of pressure, all the additional heat units showing on the thermometer. Then again comes a critical point, and however many units of heat are added after 212° Fahr. is reached, none are apparent till the water becomes vapour or steam at the 212° Fahr. It is found that every pound of water at 212° Fahr. absorbs 966 B.Th.U. to produce steam or aqueous vapour at the same temperature.

This is called the *latent heat of vapour*, and it is found that to convert water into aqueous vapour at lower temperatures than 212° Fahr. requires more latent heat than the 966 B.Th.U.

Other bodies act in similar ways in absorbing heat in transforming from the solid to the liquid state, and from the liquid to the gaseous, but their *critical temperatures* are not identical, and the amount of latent heat varies very greatly in different bodies. This latent heat is of vital importance in calculating drying capacities, and is referred to later under "Vapour."

Heat Transmission.—Heat is transmitted from its source of energy by (1) *conduction*, when the molecular motion passes through the substance of the body and thus heats more remote particles; (2) *convection*, when particles are heated and move away, carrying their thermal energy to other particles or bodies; and (3) *radiation*, when the motion passes through the ether or other intervening medium which is not heated thereby, to some other body which may absorb it. Each of these methods of transmission is used in drying machinery, while some dryers utilise all three. The subject is treated under the various methods of applying the heat, both in regard to efficiency in transmission, and economy in preventing transmission losses by means of insulation.

Specific Heat.—The addition of a certain number of units of heat to a cubic foot of water causes the increase of its temperature by a certain number (practically the same number) of degrees as marked on the thermometer. If the same heat units were added to a cubic foot of aqueous vapour at the same temperature, it would cause a very much greater increase of temperature, and if they were added to a cubic foot of air at the same temperature the increase would be greater still. This arises from a difference in heat absorbing capacity of the respective bodies, the term *specific heat* or *calorific capacity* being applied to this property. For convenience, water is taken as the standard of calorific capacity and denoted as unity, or its specific heat is 1, then aqueous vapour is ·480, while air is ·237. In other words, owing to their specific heats, the same amount of heat as will raise water 1° Fahr. will raise the same weight of aqueous vapour at the same temperature and under the same pressure $\frac{1}{\cdot 480} = 2{\cdot}05°$ Fahr., or dry air under similar conditions $\frac{1}{\cdot 237} = 4{\cdot}2°$ Fahr. Hence the specific heat of the various materials to be dried, of the water to be evaporated, of the aqueous vapour into which that water is transformed, and of the air used for the convection of the heat and the removal of the aqueous vapour, all need consideration in calculating the required quantity of heat for drying apparatus.

TABLE III.—SPECIFIC HEATS.

The calorific capacity as compared with the same weight of pure water at the same temperature, 39° Fahr., and at the same pressure, 29·921 in. of mercury.

Water	1·000	**Ammonia gas**	·508
Ice	·489	**Ether vapour**	·481
Aqueous vapour	·480	**Alcohol**	·062
Air	·237	**Alcohol vapour**	·453
Iron	·113	**Carbonic oxide gas**	·245
Gold	·032	**Graphite**	·202
Silver	·057	**Wood charcoal**	·241
Lead	·031	**Silicon crystallised**	·176

—*Ganot.*

Expansion by Heat.—All bodies expand by the action of heat. As a general rule, gases are most expansible, the liquids next, and lastly solids. In the case of liquids and solids this is measured by the increase in volume. This increase is practically uniform for air and other gases for every degree added to their temperature, when the pressure remains constant, and the *coefficient of* this *expansion* is $\frac{1}{490}$ for each Fahrenheit degree. When calculating the capacity of fans this coefficient must be allowed for, especially in dryers where air at three or more different temperatures and corresponding volumes are to be transmitted, but the expansion of solids and liquids has not much influence in connection with drying.

The expansion which is most noteworthy in connection with drying operations is that caused directly by the change of water from the liquid to the gaseous condition as vapour or steam. Thus at atmospheric pressure:—

1 cub. ft. of water at 212° weighs - 5·97 lb.,
1 cub. ft. of steam at 212° weighs - ·03826 lb.

1 lb. of water at 212° occupies - - ·0161 cub. ft.
1 lb. of steam at 212° occupies - - 26·14 cub. ft.

1 lb. of water at 212° contains - - 181·8 B.Th.U.
1 lb. of steam at 212° contains - - 1146·9 B.Th.U.

Thermal Capacity of Air.—The capability of the air for absorbing and transmitting heat are of vital importance in all calculations for drying by evaporation, hence the Table IV. will be found useful for reference, and needs no further explanation.

TABLE IV.—THERMAL CAPACITIES OF AIR.

Temperature Fahrenheit.	B.Th U. Absorbed by 1 Cub. Ft. Dry Air per Degree Fahrenheit.	B.Th.U. Absorbed by 1 Cub. Ft. Saturated Air per Degree Fahrenheit.	Cub. Ft Dry Air Warmed 1 Deg. per B.Th.U.	Cub. Ft. Saturated Air Warmed 1 Deg. per B.Th.U.
0	0·02056	0·02054	48·5	48·7
12	0·02004	0·02006	50·1	50·0
22	0·01961	0·01963	51·1	51·0
32	0·01921	0·01924	52·0	51·8
42	0·01882	0·01884	53·2	52·8
52	0·01847	0·01848	54·0	53·8
60	0·01818	0·01822	55·0	54·9
62	0·01811	0·01812	56·2	55·7
70	0·01777	0·01794	57·3	56·5
72	0·01777	0·01790	58·5	56·8
82	0·01744	0·01770	57·2	56·5
92	0·01710	0·01751	58·5	57·1
100	0·01690	0·01735	59·1	57·8
102	0·01682	0·01731	59·5	57·8
112	0·01651	0·01711	60·6	58·5
122	0·01623	0·01691	61·7	59·1
132	0·01596	0·01670	62·5	59·9
142	0·01571	0·01652	63·7	60·6
152	0·01544	0·01654	65·0	60·5
162	0·01518	0·01656	62·2	60·4
172	0·01494	0·01658	67·1	60·3
182	0·01471	0·01687	68·0	59·5
192	0·01449	...	68·9	...
202	0·01466	...	68·5	...
212	0·01406	...	71·4	...

Measurement of Heat.—Latent heat is measured by means of *calorimeters*, which are only suitable for laboratory use.

Sensible heat is measured by *thermometers* and *pyrometers*, which are necessary for constant use in connection with all economical and efficient drying operations.

For use with drying plant the thermometers, while necessarily sensitive and accurate, need to be well protected and strong. Fig. 30A shows a good form for general use, with short stem for steam pipes, radiators, &c. Fig. 30B shows the angle stem for insertion in flues, ducts, or through the walls and insulations of rooms or ovens. In each style the scale can be gauged according to requirements either in Fahrenheit or Centigrade, and to suit high or low temperatures. The special features of these thermometers are (1) the lens fronts which make the mercury column visible from a distance; (2) the space above the mercury being filled with nitrogen gas under pressure, which allows of high temperature use, and ensures accuracy whether the column is horizontal or vertical; (3) the containing socket for the mercury bulb being of thin steel accurately fitting the bulb to obtain a true metallic contact, hence the thermometer is quick in registering.

For high temperatures *pyro-*

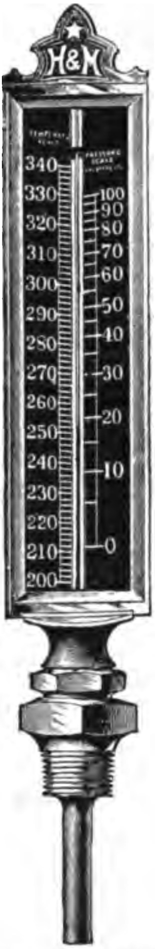

FIG. 30A.—THERMOMETER. STRAIGHT STEM.

(Cambridge Scientific Instrument Co., Ltd.)

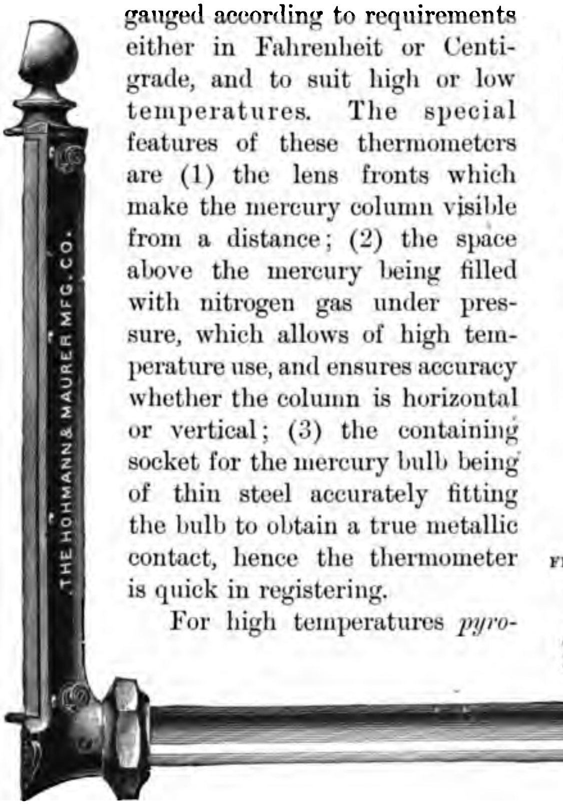

FIG. 30B.—THERMOMETER. ANGLE STEM.

(Cambridge Scientific Instrument Co., Ltd.)

meters are used. One form of these consists essentially of a coil of fine platinum wire protected by a porcelain or metal tube. It is connected to one arm of a Wheatstone's bridge by leads, while compensating leads are connected in the other arm of the bridge to eliminate the effect of changes in the length or temperature of the leads themselves. By measuring the resistance of the platinum coil, its temperature may be determined, as its resistance varies with the temperature according to an accurately known law.

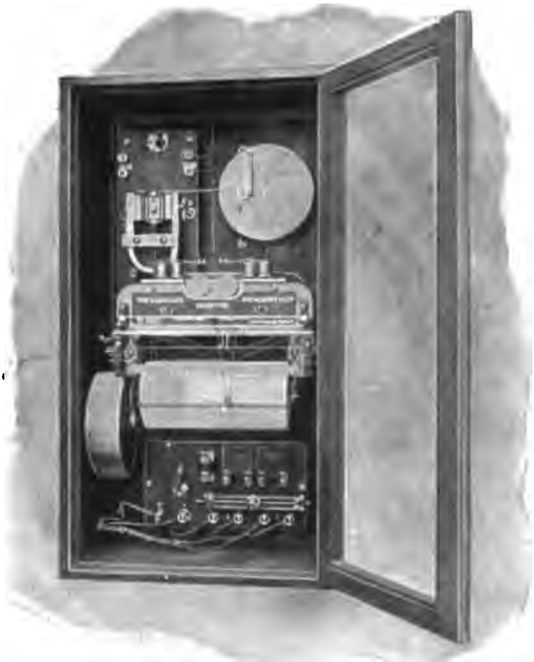

FIG. 31.—CALLENDER (PATENT) ELECTRIC RECORDER.
(Cambridge Scientific Instrument Co., Ltd.)

There are various methods of indicating and recording the results. Among the instruments used for this purpose may be mentioned:—

The *Callender* (*Patent*) *Electric Recorder* (Fig. 31), which is a Wheatstone's bridge, in which the balance on the bridge wire is obtained automatically and recorded on a chart. The charts are 10 in. in width, and are graduated so that the temperatures may be read directly. The range across the chart may be of any desired value from a few to a thousand or more degrees.

The *Whipple (Patent) Electric Temperature Indicator* (Fig. 32) is a portable instrument on the same principle as the above, but

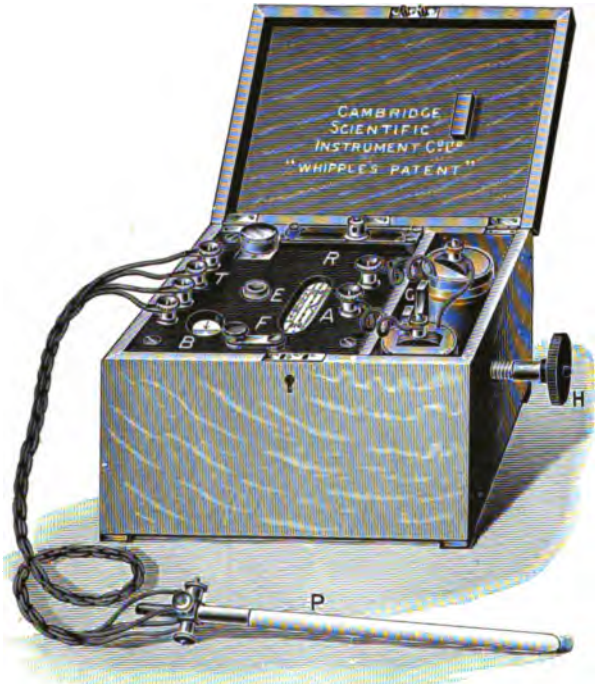

FIG. 32.—WHIPPLE (PATENT) TEMPERATURE INDICATOR.
(Cambridge Scientific Instrument Co., Ltd.)

the bridge wire is arranged compactly in a spiral form, and the balance point is obtained by hand adjustment. The scale is very open, and although the total range is 0° to 1,200° Cent., readings can be obtained to $\frac{1}{2}$° Cent. Both instruments are extremely accurate and largely used for commercial purposes. The pyrometer P is shown connected up to the bridge studs, ready for insertion into the heated space.

Fuel Values.—In designing and working all types of evaporative drying apparatus, the heat supply is of importance, and the fuel necessarily needs consideration. Table V. gives the approximate theoretical values of various fuels in heat units, and the theoretical amount of water which should be evaporated by each pound of these fuels. The figures are only capacities, however; the actual results in best working conditions would be about 50 to 60 per cent. of these amounts.

TABLE V.—CALORIFIC VALUE AND EVAPORATIVE POWER OF FUELS.

Average Samples.	Total Heat of Combustion.	Evaporative Power from and at 212 deg. Fahr.
	B.Th.U.	Lb.
Welsh anthracite	14·858	15·52
Newcastle coal	14·820	15·32
Derbyshire coal	13·860	14·34
South Yorkshire coal	14·296	14·71
Lancashire coal	13·918	14·56
Scotch coal	14·164	14·65
Irish anthracite	13·302	14·5
French anthracite	14·038	14·53
French, hard bituminous	15·525	16·10
Chilian coal	11·030	11·68
Patent fuel briquette	15·000	15·66
Lignite, Russian	14·263	14·7
Lignite, ordinary	11·444	12·0
Coke, West Warham	12·832	13·30
Woods (when dry)	7·800	8·1
Peat (fairly dry)	9·951	10·30
Petroleum	19·640	20·33

—*Seaton.*

Air.

The atmosphere consists of a mechanical mixture of 21 volumes of oxygen to 79 volumes of nitrogen, a variable quantity of aqueous vapour and small quantities of various other gases, besides traces of animal, vegetable, and mineral matter under most circumstances.

Air as a Drying Medium.—These substances form the gaseous fluid called air, and air is the most important medium for drying by evaporation It should be well borne in mind that air is only a medium or accessory, not a primary cause of drying. Rapid and thorough drying can be done in the entire absence of air as in vacuum plants. The mere presence of air is in fact an obstacle to drying, although properly applied it can be and is used in by far the largest proportion of drying installations, as the most efficient and economical medium for drying. In most installations it is used as the vehicle for (1) applying the heat, and (2) removing the vapour, which are the essential work of drying, while in some it is also used for (3) handling the material and delivering the dried product.

Heat Vehicle.—With regard to heat, the air is a bad conductor, in fact it is questionable whether it has any true conductivity, while all substances between whose particles air remains stationary offer great resistance to the propagation of heat. But the air readily absorbs heat, its specific heat being ·237, and so every unit of heat raises it above 4° Fahr. as compared with 1° Fahr. for water, further with every increase of temperature its elastic force is greater, which tends to disperse and convey its heat, thus warming the surrounding materials by convection. Its fluidity and weight tend to bring it into intimate contact with the surface of the material, thus vaporising the moisture thereon.

As a vehicle for applying heat the air thus offers great facilities, and has the further advantages that it can be applied in exact quantities whether large or small, at exact speeds whether swift or slow, at exact pressures whether high or low, at pressures which are so elastic as to be entirely uniform and not destructive of the finest fabrics, and these quantities, speeds, pressures, are under control for instantaneous application, increase, decrease, or withdrawal. The air enables any quantity of heat required to vaporise any given amount of water to be supplied at temperatures as low as the material necessitates, and as rapidly as can be allowed, while the facility of its own withdrawal saves the necessity of removing the material on the completion of the operation. Thus it will be difficult to find any other vehicle which can approach those of the air as a means of applying heat for drying purposes.

Vapour Vehicle.—As to the removal of the vaporised water, the fluidity of the air is a great advantage by enabling it to be moved by a minimum of power and with a minimum friction, also in moving it carries with it the aqueous vapour whose molecules are commingled with its own.

But in its weight the air has a beneficent property so far as facility of handling the air mixtures is concerned. Especially is this noticeable at the lower temperatures, and it is at the lower temperatures where drying is more difficult. The elastic force of aqueous vapour is regulated by its temperature, and at any given temperature a given space can only contain a fixed quantity even when saturated.

By referring to Table VI. of weights of air mixtures, it will be noted that at the pressure 29·921 in. the utmost vapour in 1 cub. ft. at 0° Fahr. is ·000079 lb. and at 32° Fahr. is ·000304 lb., while even at 92° Fahr., which is too high for some materials, the weight is still only ·002250 lb. per cubic foot.

Now these weights show how *attenuated* the *vapour* is at low and even moderate temperatures—no propeller or fan could efficiently deal with them, while even a pneumatic pump is working under strenuous conditions with an exceeding small output.

By the same table is shown the utility and the adaptability of air as a vehicle for facilitating rapid removal of this *attenuated atmosphere of vapour.* Thus 1 cub. ft. of mixture may contain

at 0° Fahr., vapour ·000079 lb., air ·0863 lb.,
i.e., air is 1,092 times as heavy;
at 32° Fahr., vapour ·000304 lb., air ·0802 lb.,
i.e., air is 263 times as heavy;
at 92° Fahr., vapour ·00225 lb., air ·0684 lb.,
i.e., air is 30 times as heavy.

Showing that when the vapour is at extreme attenuity the air is many times its weight, and acts as the necessary *ballast* to secure efficient propelling or draught. As the vapour becomes less attenuated the air is less necessary and decreases in weight by the agency of the same heat as increases the vapour.

Further, by the same table in comparing the total weights of the mixture at the several temperatures this adaptability is still further emphasised, when it is noted that for 1 cub. ft.

at 0° Fahr. total weight of mixture ·086379 lb.,
at 32° Fahr. „ „ ·080504 lb.,
at 92° Fahr. „ „ ·070717 lb.

So that as the inert air is less required for ballasting, not only is its quantity lessened, but it is so much lessened that the total weight is decreased when the propeller has an increase of the more difficult body (vapour) to cope with. While if the vapour be not present to a saturated degree, the air is still there in full weight according to the pressure and temperature.

Thus air, which is a bad conductor of heat, and whose weight tends to retard evaporation, when properly applied, is wonderfully adapted and adaptable for drying purposes, both in applying the heat and removing the vapour, especially so at low temperatures.

Air Pressure.—At the sea level weight of the air is 14·7 lb. to the square inch of surface, or as shown on the barometer 29·921 in. of the mercury column. This is taken as a point to calculate other pressures, and is called *one atmosphere.* This weight decreases as the altitude increases, so that by its pressure the height of place may be determined. The *weight* also varies with the temperature, but only in a comparatively minor degree to that of aqueous vapour, and in the opposite direction, for 1 cub. ft. under one atmosphere pressure,

at 0° Fahr., air weighs ·0863 lb., vapour ·000079 lb.;
at 32° Fahr., air weighs ·0807 lb., vapour ·000304 lb.;
air has lost ·0056 lb. only, vapour gained ·000225 lb. = 3 times;
at 212° Fahr., air weighs ·0591 lb., vapour weighs ·036820 lb.;
air has lost ·0273 lb. = $\frac{1}{3}$ loss, vapour has gained ·036741 lb. = 46,075 times.

Just as the nitrogen of the air acts as a diluent to the active properties of its oxygen, and prevents the rapid combustion of terrestrial objects by oxidation, so the weight of the air acts as a counterbalance to the energy imparted to the molecules of water when transformed by heat into aqueous vapour. The greater the pressure of the air, the more heat units are absorbed as latent heat in the internal work of the change of state and of the external work of lifting this weight, so that less evaporation occurs in the period. If this weight were removed, the transformation to vapour would be instantaneous, as is seen when under vacuum and at *boiling point*, when the *elastic force* of the vapour balances the weight of the air at that temperature. Hence the reason why under reduced air pressure, for instance on a high mountain, the air weighing less and the elastic force of the vapour remaining exactly according to its temperature, the water boils at a lower temperature, or in other words, the energy having less to spend in lifting, the more rapidly transforms the water into vapour or steam.

The weight or pressure of the superincumbent air at any time and place is usually measured by a *barometer*, but other air pressures are usually measured by *pressure gauges* of the spring type.

Barometers are mostly constructed on the principle of the Torricellian Tube, although there are *aneroid* barometers without any liquid. The tube type are more reliable and take the form of a long tube closed at the top end, while the open end rests in a cistern or is bent into siphon shape. The long tube is filled with mercury or water, then inverted over the cistern. The air pressure on the liquid in the cistern or on the open leg of the siphon maintains the liquid in the long closed tube at a height varying with the nature of the liquid and the amount of the pressure. If the liquid be water the corresponding height of column will be about 29 ft., whereas it will be about 29 in. if mercury. Hence these are divided into feet and inches respectively, and the pressure expressed as inches of mercury or feet of water—or in the French units as metres of water and millimetres of mercury.

Other air pressures and steam pressures are measured by pressure gauges which act through springs which indicate the movement of a diaphragm. This diaphragm covers a hermetically sealed space from which the air has been exhausted. As the pressure varies it causes a corresponding variation in the tension of the spring, which variation is increased by the mechanism and indicated on the dial to any required degree of accuracy. The unit here adopted is that of the number of lb. per square inch of surface or kilos per square centimetre. The

PLATE V.—DRYING MACHINERY AND PRACTICE

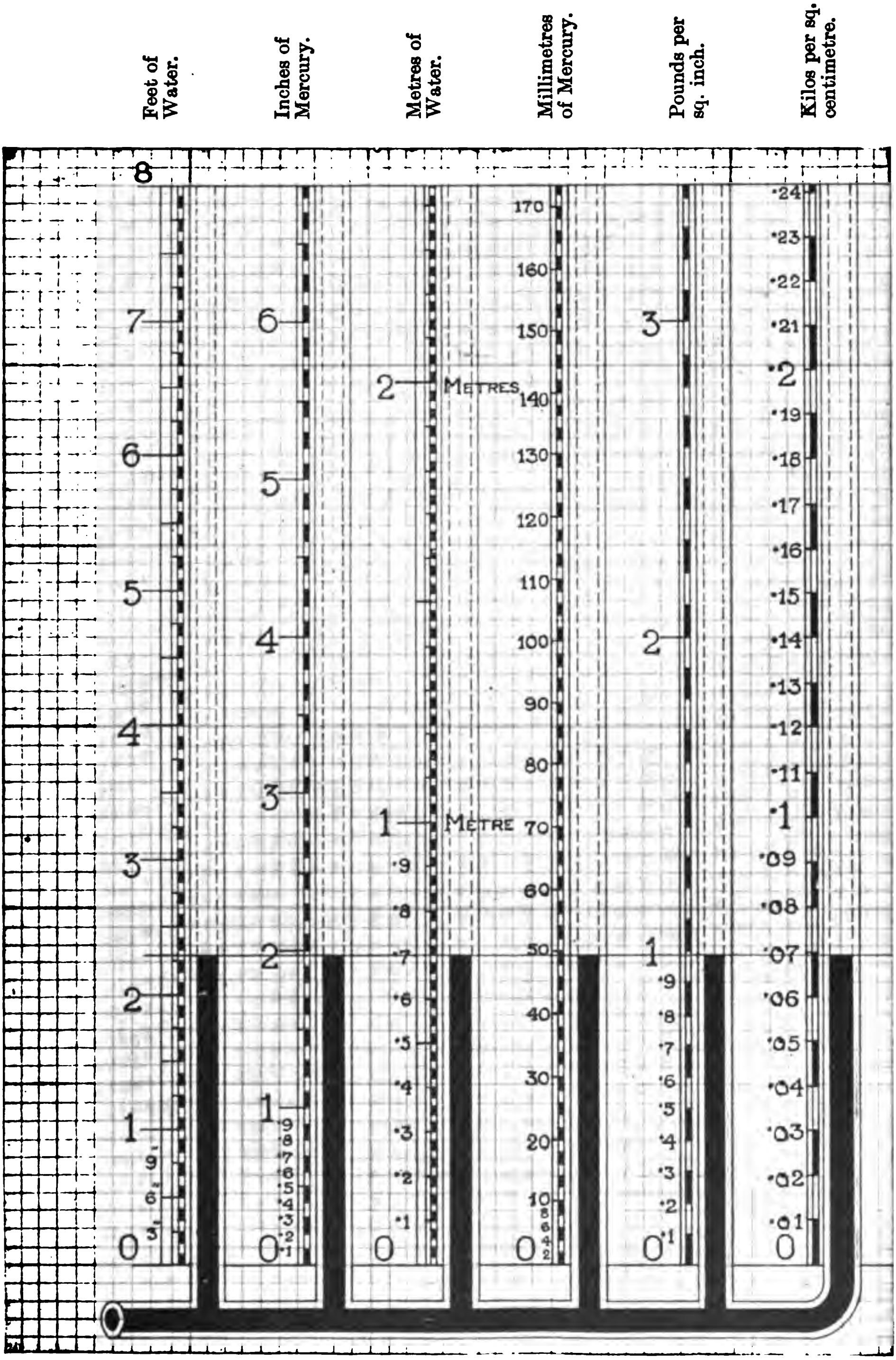

DIAGRAM I.—THE DIFFERENT EQUIVALENTS OF AIR PRESSURE.

[*To face page* 60.

Then by Table VI. we find—

Air, 52° Fahr., 25 per cent. humid, less than ·00016 lb., of vapour, *i.e.*, 3·1 per cent. humidity for 122° Fahr. making no appreciable difference to its weight.

Air, 92° Fahr., saturated, holds - - - - ·00225 lb. vapour.
Air, 92° Fahr., 75 per cent. only, holds - - ·00169 lb. „

∴ It has less vapour by - - - - - ·00056 lb.

which vapour is replaced by about $\frac{\cdot0720 - \cdot0684}{4} = \cdot0009$ lb. of dry air, showing
an increase of ·0009 – ·00056 = ·00034 lb.

Since the air enters at 122° Fahr., at 96·9 per cent. humid, weighing - - - - - - - ·0682 lb.,
and leaves at 92° Fahr., 75 per cent. humid, weighing ·070717 + ·00034 = ·071057 lb.,
∴ it is ·071057 – ·0682 = ·002857 lb. per cubic foot heavier = 4·2 per cent. heavier than at entry.

Presumably, therefore, the outlet should be at the bottom, but this is a question in which the nature and condition of the material have as usual to be fully considered before deciding on the design of the apparatus.

For instance, in drying, where the weight of the material is great compared with the moisture to be evaporated, heating of this material becomes an important factor. This heating may be by conduction or radiation, and necessarily from below, when outlets at the top are often found most economical.

Expansibility of Air.—The expansibility of air is another of its properties which has a direct bearing on its use as a drying medium. The air expands with increase of temperature similarly to the permanent gases, *i.e.*, for every added Fahrenheit degree it expands $\frac{1}{490}$ of its volume, and contracts equally for heat eliminated. As the air enters the dryer hot it is expanded, and so tends more to press itself into the material, and thus impart to the material the heat conveyed. Having lost some of its heat and incidentally vaporised the surface water it contracts. In contracting it comes away from the surface, doubly facilitating the drying by leaving the aqueous vapour more freedom to expand, and at the same time bringing away with it the associated vapour.

Thus the natural process of the air under ordinary atmospheric conditions during drying is (1) entry in a heated and expanded state, thus ensuring intimate contact with all surfaces of the material, and (2) exit in a cooled and contracted state, thus relieving the surface tension and removing the vapour. An ideal dryer would then appear to be one which followed this natural process by supplying the air to the dryer under pressure to obtain the intimate contact, and withdrawing it under partial vacuum to accelerate the vaporisation and dispersion.

But "you cannot eat your cake and have it." It is not practicable to produce artificially in bulk what Nature does in detail; in other words, you cannot be utilising a state of pressure and a state of partial vacuum in the same space at the same time. Nature is dealing with the individual molecules of air, which is a bad conductor, and conveys heat by its molecules.

The air, however, is a very adaptable vehicle, eminently and evidently intended as the drying medium, for the air can be forced into the dryer by a blast fan under pressure, the current cut off, and then the air withdrawn by an exhaust fan, thus following Nature's ordinary procedure, but increasing the efficiency by intensifying its changes. As the transmission of the heat from the molecules of air to the material is not instantaneous, nor yet is the dispersion of the vapour into the air, it would appear that a slight interval between the two processes would allow both operations to be carried out more completely, and increase the amount of the resultant drying.

These several *properties of the air* are well summarised in the Table VI., which also gives similar particulars as to aqueous vapour, and saturated mixtures of air and aqueous vapour. The table is based on the experiments of Regnault and others, but this compact and useful form has been compiled by the Sturtevant Engineering Co., Ltd., by whose permission it is used. As each characteristic is dealt with in detail in other portions of this book, it is not necessary to recapitulate here, especially as the headlines are explicit and simple.

It is, however, well to remember that in speaking of a given volume of air it is necessary to consider its pressure and its temperature in every case. With aqueous vapour temperature alone is sufficient, so long as it is a saturated

TABLE VI.—PROPERTIES OF AIR.

Vapour of water and saturated mixtures of air and vapour at different temperatures, under the ordinary atmospheric pressure of 29·921 in. of mercury.

Temperature, Degrees Fahr.	Volumes of Dry Air at Different Temperatures, the Volume at 32° being 1·000.	Weight of a Cubic Foot of Dry Air at Different Temperatures, in Lb.	Elastic Force of Vapour in Inches of Mercury, Regnault.	MIXTURES OF AIR SATURATED WITH VAPOUR.						Cubic Foot of Vapour from 1 Lb. of Water at its own Pressure in Column 4.
				Elastic Force of the Air in the Mixture of Air and Vapour in Inches of Mercury.	Weight of Cubic Foot of the Mixture of Air and Vapour.			Weight of Vapour Mixed with 1 Lb. of Air in Lb.	Weight of Dry Air Mixed with 1 Lb. of Vapour in Lb.	
					Weight of the Air in Lb.	Weight of the Vapour in Lb.	Total Weight of Mixture in Lb.			
0	·935	·0864	·044	29·877	·0863	·000079	·086379	·00092	1092·4	...
12	·960	·0842	·074	29·849	·0840	·000130	·084130	·00155	646·1	...
22	·980	·0824	·118	29·803	·0821	·000202	·082302	·00245	406·4	...
32	1·000	·0807	·181	29·740	·0802	·000304	·080504	·00379	263·81	3289
42	1·020	·0791	·267	29·654	·0784	·000440	·078840	·00561	178·18	2252
52	1·041	·0776	·388	29·533	·0766	·000627	·077227	·00819	122·17	1595
62	1·061	·0761	·556	29·365	·0747	·000881	·075581	·01179	84·79	1135
72	1·082	·0747	·785	29·136	·0727	·001221	·073921	·01680	59·54	819
82	1·102	·0733	1·092	28·829	·0706	·001667	·072267	·02361	42·35	600
92	1·122	·0720	1·501	28·420	·0684	·002250	·070717	·03289	30·40	444
102	1·143	·0707	2·036	27·885	·0659	·002997	·068897	·04547	21·98	334
112	1·163	·0694	2·731	27·190	·0631	·003946	·067046	·06253	15·99	253
122	1·184	·0682	3·621	26·300	·0599	·005142	·065042	·08584	11·65	194
132	1·204	·0671	4·752	25·169	·0564	·006639	·063039	·11771	8·49	151
142	1·224	·0660	6·165	23·756	·0524	·008473	·060873	·16170	6·18	118
152	1·245	·0649	7·930	21·991	·0477	·010716	·058416	·22465	4·45	93·3
162	1·265	·0638	10·099	19·822	·0423	·013415	·055715	·31713	3·15	74·5
172	1·285	·0628	12·758	17·163	·0360	·016682	·052682	·46338	2·16	59·2
182	1·306	·0618	15·960	13·961	·0288	·020536	·049336	·71300	1·402	48·6
192	1·326	·0609	19·828	10·093	·0205	·025142	·045642	1·22643	·815	39·8
202	1·347	·0600	24·450	5·471	·0109	·030545	·041445	2·80230	·357	32·7
212	1·367	·0591	29·921	0·000	·0000	·036820	·036820	Infinite.	·000	27·1

vapour, otherwise the degree of humidity if with air, or the amount of superheat if in vacuum, must be considered. As in drying operations the pressures, temperatures, and degrees of saturation are continually changing, it will be simplest to calculate both air and vapour as well as their mixtures in weights, preferably pounds, and then extend where necessary into volumes.

In the tables only one *pressure* is dealt with, but that is the one approximately obtaining under all usual practice where air is utilised as the drying medium. The artificial variations are not usually so different as to materially affect the results. Where air is not present, as in vacuum plants, then the pressures are so far dispensed with, as in any case it is temperature, not pressure, which decides the weight of the vapour which may be contained in a given space.

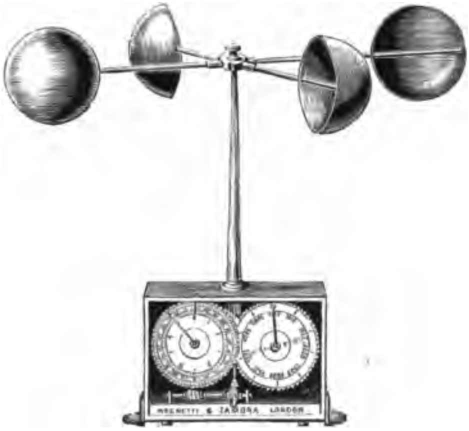

FIG. 33.—ROBINSON'S ANEMOMETER. (Negretti & Zambra.)

Air Currents.—As a given space can only contain a definite quantity of vapour at any given temperature, the importance of prompt removal becomes obvious, while a given volume of air at the same temperature can only carry this same definite amount of vapour, hence the urgent necessity of further volumes of air through the space. In other words, at a given temperature the vaporisation and drying will be dependent on the rapidity of the removal of the vapour by the air or otherwise. When air is the vehicle, this can readily be regulated by the velocity of the air current, hence the measurement of the currents becomes of great importance.

The currents are measured by *Anemometers*, of differing types and forms according to the conditions under which they are to be used. For measuring the velocities of winds in the open, the *Robinson anemometer* (Fig. 33) is universally adopted as the standard type. The four hemispherical cups attached to the ends of equal horizontal arms turn freely about the vertical axis. By worm and wheel reduction gear the revolutions are shown on a dial, which indicates the actual velocity for any definite time, as noted by watch, the inner scale indicating in 5 miles up to 505 miles, and the outer scale $\frac{1}{10}$ mile up to 5 miles, or if on metric system, $\frac{1}{10}$ km. to 10 km. The gear is contained in a cast-iron box, and has a strong glass front in a frame, ready to fix in any open space.

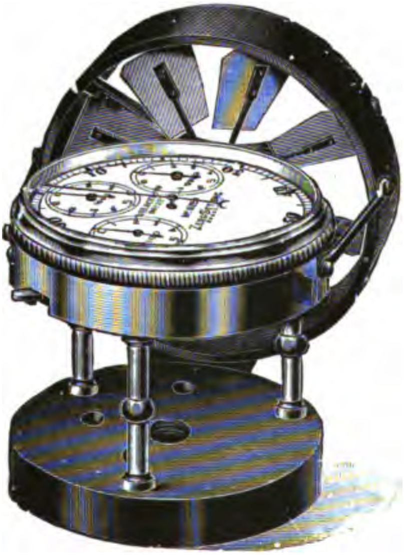

FIG. 34.—DISC FAN AIR METER.
(Negretti & Zambra)

For measuring air currents in rooms or ducts, the form of anemometer shown in Fig. 34 is used, and is generally called an *air meter* to distinguish it from the Robinson's type. It is a portable instrument needing no fixing, which by means of the disc fan and internal worm gearing indicates the air velocity in feet. With six dials it will record up to 10,000,000 feet. As it can be readily set to zero each time, the velocity is easily obtained by dividing the number of feet recorded, by the time unit, whether seconds or minutes. The disconnector allows of the action being thrown in and out of gear to obtain accuracy of time. Having obtained the velocity, of course the volume can be calculated by multiplying by the area of the duct or inlet where the air meter is placed.

For example, if the air meter registers 100 ft. in one minute, and the inlet measures 6 in. × 3 in., then—

$$\begin{aligned}\text{Volumes} &= \frac{100 \times 6 \times 3}{12 \times 12} \text{ cub. ft. per minute.}\\ &= 100 \times \tfrac{1}{8} \quad \text{,,} \quad \text{,,}\\ &= 12\tfrac{1}{2} \quad \text{,,} \quad \text{,,}\end{aligned}$$

For measuring the velocity of the current in ducts, *Biram's air meter* (Fig. 52), which is described under ducts, is a convenient form; while for inaccessible places and irregular spaces, the *syphon draft gauge*, shown in Fig. 48, works on the principle that a difference of pressure causes a corresponding difference of velocity.

Vapour.

Vapour, whether of water or other substance, is the aeriform state which that substance assumes under the influence of heat energy, but it is sometimes restricted in its application to the gaseous form of those bodies which usually exist as solids or liquids, and those bodies which at normal temperatures and normal pressures are gaseous are called gases or permanent gases. As, however, all known gases have now been liquefied, vapours and gases are proved to be physically the same. *Aqueous vapour* is the only vapour of interest with regard to drying machinery, although the various siccatives are used for drying paints and varnishes, while enamelled and japanned goods are "stoved" to dry their respective coats. Steam is only another term applied to aqueous vapour produced under different conditions of pressure. While *vaporisation* of water goes on at all temperatures and pressures, forming aqueous vapour, *ebullition* or *boiling*, forming steam, only occurs when the elastic force of the water is equal to the pressure of the atmosphere in the vessel where it occurs. If this varies from the normal temperature of boiling point, 212° Fahr., it is because the pressure in the vessel has been increased or decreased from the normal pressure of 29·921 in. of mercury. When steam, however, is taken away from its water and superheated, it has different properties, becoming more in accord with the permanent gases.

Aqueous vapour has some striking and important properties different from air and the permanent gases, these properties, which are conspicuous in drying, being:—

1. *Expansibility.*—This is most prominent at the instant

of change from water to vapour, when, as the result of the latent heat, it suddenly increases its volume by about 1,700 times, thus tending enormously to remove the vapour from the solid material. After this increase, from change of state, in an unsaturated aqueous vapour there is a regular increase of $\frac{1}{490}$ for every Fahrenheit degree, as with air and the permanent gases, but as specific heat of aqueous vapour is ·480 the effect of every B.Th.U. of heat is an increase in volume of $\frac{1}{490 \times \cdot 480} = \frac{5}{1,176}$. But so soon as the vapour becomes saturated, although the elastic force remains the same, no expansion can take place, hence the necessity of removing the vapour as rapidly as possible after formation. For, while unsaturated vapours act exactly as other gases according to the pressure and temperature, with saturated vapours temperature is all powerful and independent of the pressure. Saturated vapours cannot be compressed, as any pressure greater than their elastic force transforms them to the liquid state again. The increase of pressure under the influence of temperature, however, is most remarkable as will be seen by the tables: at 0° Fahr. the *elastic force* is ·044 in. of mercury, at 32° Fahr. it becomes ·181 in., *i.e.*, a rise of 32° causes four times the force; at 52° Fahr. it is ·388 in., thus 20° Fahr. more than doubles the force. On comparing this with the coefficient of expansion for fixed gases, viz., $\frac{1}{490}$, the difference is apparent (see also page 52).

2. *Weight* is a noticeable property of vapour in respect to drying. It has been noted as to the attenuated state at low temperatures, for instance at 0° Fahr., the weight is only ·000079 lb. in a cubic foot. An increase of temperature, however, increases its weight, or rather the weight which a cubic foot can contain increases with every rise of temperature and that quite irrespective of the atmospheric pressure. Thus at 32° Fahr. a cubic foot can contain ·000304 lb. or nearly four times the quantity at 0° Fahr., at 212° Fahr. a cubic foot can contain ·036820 lb. *i.e.*, 120 times the weight for a rise 180° Fahr. Whereas air at 212° Fahr. weighs ·0807 − ·0591 = ·0216 lb. less than at 32° Fahr. In other words, while at increased temperatures less air and other gases can be contained

in an equal space at a constant pressure, with saturated vapour the higher the temperature the more can be contained in the same space and that whether the pressure be more or less. Hence in dealing with drying problems it is essential to treat the saturated mixtures of air and vapour as two parts, having properties differently affected by similar changes of temperature and pressure.

The actual weight of moisture in saturated vapours is small even at high temperatures, and are much less than the weight of air at similar temperatures. Thus while at 0° Fahr. 1 cub. ft. at normal atmospheric pressure of dry air weighs ·0864 lb., vapour only weighs ·00079 lb., but its elastic force is only ·044 lb.; but at 212° Fahr., dry air, which decreases in weight on increase of temperature, still weighs ·0591 lb. per cubic foot, whereas vapour, which increases in weight with every rise of temperature and at 212° Fahr. has an elastic force of 29·921 lb. the equivalent to air, still only weighs ·03682 lb., about two-thirds of the air weight.

The increased weight which can be contained in a cubic foot of space varies as shown in Table VI. according to the temperature whether the space contains air or not. Table VII. below deals with this varied capacity in relation to the air in the space. Taking the weight of vapour possible in 1 cub. ft. of air at 52° Fahr., it shows the weights which the same weight of air will contain at different relative humidity for the same temperature. Also this table shows the increased weights the initial cubic foot of air would contain if raised in temperature and moistened to varying percentages of humidity. Taking the extremes of the table, then it is shown:—

(*a*.) 1 cub. ft. of air at 52° Fahr. contains ·00006 lb. of vapour when 10 per cent. saturated.

(*b*.) If this initial cubic foot of air remain at the same temperature (52° Fahr.), but becomes 100 per cent. saturated, it then contains ·00064 lb. of vapour.

> It will be noted that this weight, ·00064 lb., is more than shown in Table VI. for 1 cub. ft. of air at 52 per cent. Fahr. (·000622 lb.). The increase arises from the fact that the original cubic foot has increased in volume by the addition of the vapour.

TABLE VII.—INFLUENCE OF TEMPERATURE UPON VAPOUR CAPACITY OF AIR.

Temperature, Degrees Fahrenheit.	Dry Air.		Vapour Capacity in Pounds of Initial Cubic Feet of Dry Air at 50° when Expanded by given Temperature and by Humidity.									
	Weight of 1 cub. ft. in Pounds.	Relative Volume of Initial Weight.	10 Per Cent.	20 Per Cent.	30 Per Cent.	40 Per Cent.	50 Per Cent.	60 Per Cent.	70 Per Cent.	80 Per Cent.	90 Per Cent.	100 Per Cent.
52	·0776	1·	·00006	·00012	·00019	·00025	·00032	·00038	·00044	·00051	·00057	·00064
62	·0761	1·02	·00009	·00018	·00027	·00036	·00045	00055	·00064	·00073	·00082	·00092
72	·0747	1·04	·00013	·00025	·00038	·00051	·00064	·00077	·00090	·00104	·00117	·00130
82	·0733	1·06	·00018	·00036	·00054	·00072	·00090	·00108	·00126	·00145	·00164	·00183
92	·0720	1·08	·00024	·00049	·00077	·00099	·00124	·00150	·00175	·00201	·00228	·00254
102	·0707	1·10	·00033	·00065	·00101	·00135	·00170	·00245	·00248	·00277	·00314	·00353
112	·0694	1·12	·00045	·00090	·00136	·00183	·00231	·00280	·00329	·00381	·00433	·00485
122	·0682	1·14	·00059	·00119	·00182	·00246	·00311	·00378	·00447	·00519	·00590	·00666
132	·0671	1·16	·00078	·00158	·00242	·00328	·00417	·00510	·00605	·00705	·00806	·00913
142	·0660	1·18	·00102	·00208	·00318	·00432	·00555	·00684	·00812	·00952	·01098	·0124
152	·0649	1·20	·00131	·00270	·00417	·00572	·00734	·00912	·0110	·0130	·0156	·01743
162	·0638	1·22	·00169	·00350	·00545	·00753	·00983	·0126	·0149	·0179	·0201	·0246
172	·0628	1·24	·00216	·00452	·00708	·00995	·0130	·0166	·0206	·0250	·0300	·0360
182	·0618	1·26	·00272	·00578	·00920	·0131	·0175	·0227	·0288	·0360	·0446	·0553

(*c.*) If this initial cubic foot of air at 52° Fahr. be raised to 182° Fahr. and saturated with vapour to 100 per cent., it will contain ·0553 lb. of vapour. That is, a rise in temperature of from 52° to 182° Fahr. has made a difference in vapour weight from ·00064 lb. to ·0553 lb., over eighty-six times as much, or in other words, the capacity of a given weight of air at 52° Fahr. to carry vapour is increased above eighty-six times if that same weight be raised to 182° Fahr. and allowed to freely expand.

The question of free expansion is of considerable importance, as by Table VI. it will be seen that the capacity of 1 cub. ft. of air at 182° Fahr. is only ·020536 lb. as compared with the above ·0553 lb.

3. *Pressure.*—Practically outside pressures have no influence as to the quantity of vapour which can be contained in a given space, as the molecules of vapour commingle with the atmospheric molecules in such a manner that the effect is the same as if it were a vacuum. The same density of vapour is obtained at a given temperature whether the atmosphere is absent or present under high or low pressures. So the same space can contain the same weight of vapour regardless of the weight of the air in the same space. It is found, however, that the evaporation does not go on so rapidly under the high pressure, as the heat has more external work to perform in lifting this extra weight. It is also found that the air is not similarly insensible to the presence of the vapour, for as the vapour increases in force and density the air in the same space is decreased. Thus a cubic foot at 29·921 in. pressure at 0° Fahr. of dry air weighs ·0864 lb., and vapour weighs ·000079 lb., but in a saturated mixture of the air and vapour a cubic foot at the same temperature and pressure weighs ·086379 lb., made up of the vapour ·000020 lb. as before, but the air in the cubic foot is only ·0863 lb., having had ·0001 lb. displaced. This feature is the more noticeable at higher temperatures, thus at 32° Fahr. and 29·921 in. pressure dry air weighs ·0807 lb. per cubic foot. But a saturated mixture of air and vapour at the same temperature and pressure weighs ·080504 lb., of which ·000304 lb. is vapour, hence there is only ·0805 lb. of air left, which shows a displacement of ·0002 lb. per cubic foot. This displacement increases till, at 212° Fahr. and under

normal atmospheric pressure, the air is practically all displaced by the pressure of the vapour. Table VIII. gives a ready means of realising the capacity of vapour absorption of air at various temperatures, and is often useful for rough calculations, but it must be remembered that the pressure must be normal (29·921 in. of mercury). In all detailed calculations Tables VI. and XXII. will be found more convenient and more accurate.

Table VIII.—Vapour Weights in Grains

Which air is capable of absorbing to the point of maximum saturation, per cubic foot, for various temperatures at ordinary atmospheric pressure (29·921 in. of mercury).

Degrees Fahrenheit.	Grains in a Cubic Foot.	Degrees Fahrenheit.	Grains in a Cubic Foot.	Degrees Fahrenheit.	Grains in a Cubic Foot.
10	1·1	60	5·82	115	30·0
15	1·31	65	6·81	130	42·5
20	1·56	70	7·94	141	58·0
25	1·85	75	9·24	157	85·0
30	2·19	80	10·73	170	112·5
32	2·35	85	12·43	179	138·0
35	2·59	90	14·38	188	166·0
40	3·06	95	16·60	195	194·0
45	3·61	100	19·12	212	265·0
50	4·24	105	22·0	...	...
55	4·97	110	25·5	...	...

Vapour Indications and Measurements.—As explained in Chapter I., the quantity of vapour in the air is measured by hygrometers, of which the wet and dry bulb type is the most usual, and can be readily made on the spot by means of two ordinary thermometers, one thermometer (dry) recording, as usual, the temperature, and the other can be kept wet by means of a piece of ordinary linen and a glass of water. By noting the two temperature records, the degree of humidity can be readily found by Table IX. For instance:—

If the dry bulb records 42° Fahr., and the wet bulb records 32° (=42−10°) Fahr., then reading under the 10° difference on the 42° line, it is seen that the air is 40 per cent. saturated, or contains 40 parts out of each 100 it is capable of absorbing at 42° Fahr.

TABLE IX.—HYGROMETER (DRY AND WET BULB) INDICATOR.

Temperature of the Air, Degrees Fahrenheit.	Difference of Temperature in the Wet Bulb Thermometer.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Degrees of Humidity, Saturation being 100.																							
32	87	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
42	92	85	78	72	66	60	54	49	44	40	36	33	30	27	...	...	...	...	...	...	...	...	...	...
52	93	86	80	74	69	64	59	54	50	46	42	39	36	33	30	27	25	...	...	...	...	...	...	...
62	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35	32	30	28	26	24	...	...	...	...
72	94	89	84	79	74	69	65	61	57	54	51	48	45	42	39	36	34	32	30	28	26	24	23	22
82	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42	40	38	35	33	31	29	27	26	25
92	95	90	85	81	77	73	70	66	62	59	56	53	50	47	45	43	41	38	36	34	32	30	28	26

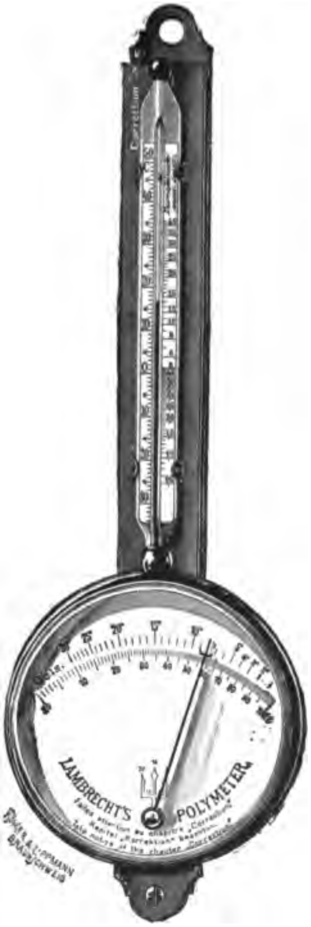

FIG. 35.—LAMBRECHT'S VAPOUR POLYMETER.
(Negretti & Zambra.)

Means of indicating variations of humidity in the air, which do not allow of measuring the degree of these variations, are usually called *hygroscopes,* substances to readily absorb moisture from the air are said to be *hygroscopic.* The *hygrodeik* and *psychrometer* have been explained and illustrated in Chapter I., as applied to their several purposes.

In *Lambrecht's Polymeter* are combined the means of taking many measurements in relation to vapour and air. As illustrated in Fig. 35, it consists of a thermometer and a hair-hygrometer, each provided with two scales. The thermometer has on the left-hand side the usual Fahrenheit scale of temperature, from which can be read the temperature of the air. On the right hand of the thermometer is a scale of the elastic force of vapour in millimetres of mercury. The lower scale on the hygrometer dial shows the percentage of moisture in the atmosphere, while from its upper scale the dew point can be determined, and the actual weight of moisture contained in a cubic metre.

CHAPTER V

METHODS OF APPLYING THE HEAT

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As the evaporation of moisture depends on the temperature, it is apparent that the more direct the application of the heat, and the more intense that heat, the more rapid and economical will be the evaporation. For all practical purposes artificial heat is obtained by combustion of coal, peat, wood, oil, and spirit. One pound of the carbon in these or any other fuel will during combustion produce 14,500 B.Th.U., however fast or slow the combustion may occur. The more rapid the combustion, the more intense the temperature produced and the density and elastic force of the vapour produced. Hence it would appear that efficiency in drying could be readily obtained by the rapid combustion of a small amount of fuel, especially as the vapour capacity increases more rapidly than the temperature.

The factor which governs the heat to be applied is, however, one which must be very carefully considered in every case, that is the nature of the material itself as regards heat. While it invariably requires a certain quantity of heat units to vaporise a given weight of water at any particular temperature, whatever material it may be associated with, and whatever may be the mode of association. At the same time, the heat cannot be put into the water without bringing the material to the same temperature, and to bring the material to the same temperature will require more or less heat according to the specific heat of that particular material. Hence the sum of the heat required by the water and that required by the material may be so relatively great that if applied in a short time or an intense form it may, and most probably would, cause changes in the material other than mere drying, and these changes may be detrimental.

Further, different materials are found to absorb heat at different speeds owing to variations in their conductivity, and thus the heat if supplied too rapidly might do damage to the exposed surfaces before it could permeate the inner portions of the mass. Some substances would sublime at the surface before the bulk was evenly heated, while others would char or crack. So that in every case of drying this question of the idiosyncrasies of material is of primary importance in deciding the method of applying the heat.

A point which also needs watching is the action when the material is thoroughly warmed, and the drying near completion. While the material was wet, the water and material greedily absorbed heat, thus they could receive intense heat readily and without injury. But the same intensity may be quite unabsorbable when the material is warmed and the water vaporised. For instance, if a wet cloth is held in front of a bright fire there is profuse evaporation and no injury, but so soon as even one portion gets dry, the part soon chars with only the same intensity of heat. This fact regulates the temperature at which the heat can be applied, and makes the more prominent the necessity for having some means of preventing any sudden rise of temperature in the dryer from this cause. Here air, owing to its bad conductivity, may be reliably used as the medium for safety.

Sources of Heat.

Solar Heat.—The heat of the sun is, of course, the cheapest means of drying, but is so unreliable in quantity and continuity that the risks attending its use are great. The liability of showers occurring to undo the results has also to be considered, so that as a direct means solar heat takes a minor place in most commercial drying except for agricultural purposes.

But indirectly the sun's heat by warming the atmosphere and causing the air currents is largely used both on floors, gantries, pans, and sheds. The drying thus performed is comparatively slow under ordinary circumstances especially in our climate, but it is of a nature which ensures that all "air-dried" goods universally have the preference over artificially dried ones. This would lead to the scientific following of Nature's processes in artificial drying, and it will generally be found that the nearer Nature's process is copied the better the product. In fact there appears every reason that artificial drying should merely be a carefully regulated and accelerated copy of "air drying."

Direct Firing.—The system of direct firing, that is, of the furnace being part of the dryer, as kilns and stoves, or in close contact, as with floors, pans, cylinders, enables great economies to be made in fuel combustion for the heat actually put into the dryer. But this heat being intense may be injurious to the material and so limits the uses of such dryers to the less heat-sensitive substances. And unless the hot gases are retained in the dryers ample time they may pass through and away while still retaining considerable vaporising or drying capacity. For while the hotter the gases leave the dryer the more vapour they can carry, and hence if they are carrying their adequate burden of vapour the more economical their use. At the same time, if they pass away inadequately vapour laden then by that amount they become uneconomical. Many of the older cylinder dryers, copied from the roaster and calciners, are extremely wasteful, while some of the newer designs really revert from the direct firing into a heater with a chamber in place of the radiators, and thus secure the advantages of direct firing plus the adaptability and control attached to heaters.

Where direct firing is used for heat by conduction from below, as in drying floors and pans with flues extending beneath, the great differences of temperature at the various portions, according to the distance from the furnace, lead to considerable variations of result or increased labour. At the same time, the heat is very rapidly dissipated in all directions without adequately performing its functions of vaporising. Where the drying floor is enclosed, the air next the floor on becoming heated promptly rises to the top of the room without coming in full contact with the materials to be dried, and tends to escape with only a slight burden of vapour.

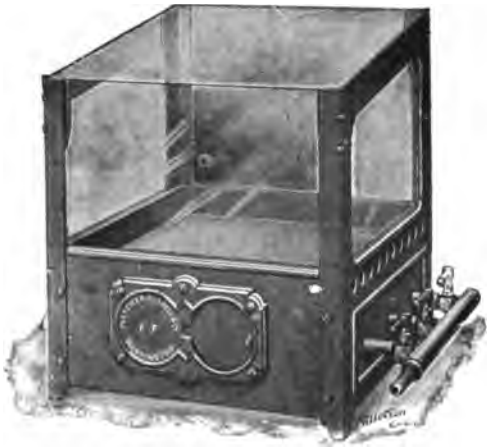

FIG. 36.—LABORATORY SAND BATH.
(Fletcher, Russell, & Co, Ltd.)

The question of *contamination* by the *products of combustion* must necessarily be considered where they are allowed to enter the dryer, although with coke and liquid fuel they may not be so objectionable as with coal. The materials which will stand the heat of direct firing are not, as a rule, injured by the products of combustion if the combustion is complete, but it may decide the type of dryer in particular cases. In laboratories considerable use is made of the direct firing with conduction and radiant heat in sand baths of various designs. The quantities being small the losses are not worth consideration, while the sand bath tends to equalise the distribution of the heat. The *Laboratory Sand Bath* (Fig. 36) is gas fired beneath the bath. The temperature can be regulated by the three burners, while the fumes, if objectionable, can be localised, and as the back is open they can be led to a flue. The removable glass sides allow of full view of the material during the process.

Hot Blast.—A hot blast dryer generally only differs from a direct fired one in that the fire is a little further away, or the fire is used primarily for some other purpose, such as a retort, cupola, blast furnace, or kiln, and the surplus delivered to the dryer. Hence it generally has the same advantages and disadvantages, besides requiring even more control, as it may be delivered under considerable pressure as well as intensity of heat. In some such, radiators of the cast-iron studded tubular type (Fig. 38) are advantageously used to ensure a clean current more under control than the direct hot blast.

Warm Blast.—Warm blast produced by heaters and fans or propellers gives all the advantages of control in heat, speed, and fluidity necessary to produce an artificial atmosphere with accelerated capacity for vaporisation and drying. Hence it is with warm blast apparatus that the bulk of dryers are worked.

Hot Water.—Owing to the low heat capacity of water compared with its temperature, it is not used much in drying machinery, and only has to be considered in connection with the condensation of the steam.

Steam.—Steam being light in weight, easy to transmit and to regulate in quantity and temperature, is the main medium for localising the heat. The latent heat given off on condensation is of the utmost utility in drying as it is in heating generally. The rapidity with which it imparts its heat adds greatly to its advantage. The fact that the exhaust steam from an engine carries a large percentage of its heat, makes it that in many works by using the exhaust, drying can be done without any fuel cost. This heat would otherwise simply go to waste. The tables of steam properties show the vast importance of the latent heat in relation to vaporising and drying.

Table X.—Properties of Saturated Steam.

Pressure in Lb. per Sq. In. above Vacuum.	Temperature in Degrees Fahrenheit.	Total Heat in B.Th.U. from Water at 32°.	Heat in Liquid from 32° in B.Th.U.	Heat of Vaporisation, or Latent Heat in B Th.U.	Density or Weight of Cub. Ft. in Lb.	Volume of 1 lb. in Cub. Ft.	Factor of Equivalent Evaporation at 212°.	Total Pressure above Vacuum.
1	101·99	1113·1	70·0	1043·0	0·00299	334·5	·9661	1
2	126·27	1120·5	94·4	1026·1	0·00576	173·6	·9738	2
3	141·62	1125·1	109·8	1015·3	0·00844	118·5	·9786	3
4	153·09	1128·6	121·4	1007·2	0·01107	90·33	·9822	4
5	162·34	1131·5	130·7	1000·8	0·01366	73·21	·9852	5
6	170·14	1133·8	138·6	995·2	0·01622	61·65	·9876	6
7	176·90	1135·9	145·4	990·5	0·01874	53·39	·9897	7
8	182·92	1137·7	151·5	986·2	0·02125	47·06	·9916	8
9	188·33	1139·4	156·9	982·5	0·02374	42·12	·9934	9
10	193·25	1140·9	161·9	979·0	0·02621	38·15	·9949	10
15	213·03	1146·9	181·8	965·1	0·03826	26·14	1·0003	15
20	227·95	1151·5	196·9	954·6	0·05023	19·91	1·0051	20
25	240·04	1155·1	209·1	946·0	0·06199	16·13	1·0099	25
30	250·27	1158·3	219·4	938·9	0·07360	13·59	1·0129	30
35	259·19	1161·0	228·4	932·6	0·08508	11·75	1·0157	35
40	267·13	1163·4	236·4	927·0	0·09644	10·37	1·0182	40
45	274·29	1165·6	243·6	922·0	0·1077	9·285	1·0205	45
50	280·85	1167·6	250·2	917·4	0·1188	8·418	1·0225	50
55	286·89	1169·4	256·3	913·1	0·1299	7·698	1·0245	55
60	292·51	1171·2	261·9	909·3	0·1409	7·097	1·0263	60
65	297·77	1172·7	267·2	905·5	0·1519	6·583	1·0280	65
70	302·71	1174·3	272·2	902·1	0·1628	6·143	1·0295	70
75	307·38	1175·7	276·9	898·8	0·1736	5·760	1·0309	75
80	311·80	1177·0	281·4	895·6	0·1843	5·426	1·0323	80
85	316·02	1178·3	285·8	892·5	0·1951	5·126	1·0337	85
90	320·04	1179·6	290·0	889·6	0·2058	4·859	1·0350	90
95	323·89	1180·7	294·0	886·7	0·2165	4·619	1·0362	95
100	327·58	1181·9	297·9	884·0	0·2271	4·403	1·0374	100
105	331·13	1182·9	301·6	881·3	0·2378	4·205	1·0385	105
110	334·56	1184·0	305·2	878·8	0·2484	4·026	1·0396	110
115	337·86	1185·0	308·7	876·3	0·2589	3·862	1·0406	115
120	341·05	1186·0	312·0	874·0	0·2695	3·711	1·0416	120
125	344·13	1186·9	315·2	871·7	0·2800	3·571	1·0426	125
130	347·12	1187·8	318·4	869·4	0·2904	3·444	1·0435	130
140	352·85	1189·5	324·4	865·1	0·3113	3·212	1·0453	140
150	358·26	1191·2	330·0	861·2	0·3321	3·011	1·0470	150
160	363·40	1192·8	335·4	857·4	0·3530	2·833	1·0486	160
170	368·29	1194·3	340·5	853·8	0·3737	2·676	1·0502	170
180	372·97	1195·7	345·4	850·3	0·3945	2·535	1·0517	180
190	377·44	1197·1	350·1	847·0	0·4153	2·408	1·0531	190
200	381·73	1198·4	354·6	843·8	0·4359	2·294	1·0545	200
225	391·79	1201·4	365·1	836·3	0·4876	2·051	1·0576	225
250	400·99	1204·2	374·7	829·5	0·5393	1·854	1·0605	250
275	409·50	1206·8	383·6	823·2	0·5913	1·691	1·0632	275
300	417·42	1209·3	391·9	817·4	0·644	1·553	1·0657	300
325	424·82	1211·5	399·6	811·9	0·696	1·437	1·0680	325
350	431·90	1213·7	406·9	806·8	0·748	1·337	1·0703	350
375	438·40	1215·7	414·2	801·5	0·800	1·250	1·0724	375
400	445·15	1217·7	421·4	796·3	0·853	1·172	1·0745	400
500	466·57	1224·2	444·3	779·9	1·065	·939	1·0812	500

—*Steam.*

Electric Heat.—Electric heat is occasionally used for drying small articles by enclosing an incandescent burner in a small oven, with shelves for the article and pipe for the vapour. A more special method is one patented by Edison for drying metallic ribbon strips during process of manufacture. The method here adopted is by passing through the actual strip to be dried a current of electricity sufficiently powerful to vaporise the water or moisture upon it. By graduation of the current this offers a very elegant and convenient method of applying exactly the requisite heat, quite locally and for the necessary time only. This method can be applied in any position relatively to the machine, and at any stage of the manipulation.

TABLE XI.—TEMPERATURE AND PRESSURE OF STEAM FOR EACH HALF INCH OF VACUUM.

Inches of Vacuum.	Temperature, Degrees Fahrenheit.	Absolute Pressure, Lb. per Sq. In.	Inches of Vacuum.	Temperature, Degrees Fahrenheit.	Absolute Pressure, Lb. per Sq. In.
0	212·00	14·697	15	178·96	7·329
½	211·15	14·451	15½	177·44	7·084
1	210·29	14·206	16	175·87	6·838
1½	209·42	13·960	16½	174·26	6·592
2	208·54	13·715	17	172·59	6·347
2½	207·64	13·469	17½	170·86	6·101
3	206·73	13·223	18	169·07	5·856
3½	205·80	12·978	18½	167·23	5·610
4	204·86	12·732	19	165·31	5·364
4½	203·91	12·487	19½	163·32	5·119
5	202·94	12·241	20	161·25	4·873
5½	201·95	11·995	20½	159·09	4·628
6	200·95	11·750	21	156·83	4·382
6½	199·93	11·504	21½	154·46	4·136
7	198·89	11·259	22	151·97	3·891
7½	197·83	11·013	22½	149·34	3·755
8	196·75	10·767	23	146·55	3·410
8½	195·65	10·522	23½	143·59	3·164
9	194·53	10·276	24	140·42	2·918
9½	193·39	10·031	24½	137·01	2·673
10	192·23	9·785	25	133·32	2·427
10½	191·03	9·539	25½	129·31	2·172
11	189·81	9·294	26	124·89	1·526
11½	188·57	9·048	26½	119·94	1·680
12	187·30	8·803	27	114·34	1·435
12½	186·00	8·567	27½	107·84	1·189
13	184·66	8·311	28	100·05	0·944
13½	183·29	8·066	28½	90·24	0·698
14	181·88	7·820	29	76·80	0·453
14½	180·44	7·575	29½	54·21	0·207

Heaters.

Heat Transmission.—As previously stated, heat is distributed by radiation, conduction, and convection. Most practical means of utilising heat, however, utilise two or more of these in combined operation. For instance, take an ordinary boiler. The combustion of the fuel of whatever kind in the furnace generates a certain quantity of heat energy; some of this at once by radiation heats the air, the unconsumed fuel, and the material of the boiler. The air carries its heat away and warms by convection the tubes of the boiler, the flues, and the outside atmosphere above the chimney. The heated materials of the boiler being of metal conduct their heat through their own substance, and warm the water and the surroundings by conduction. This heated water delivers its heat to the steam by convection through its own particles. The steam leaving the boiler carries its heat and warms the pipes, valves, and the vessels to which it is passed by convection. If this vessel be of metal the heat is conducted through its own substance and warms the surroundings, if good conductors, by conduction, if the atmosphere, by radiation. Hence a metallic vessel which receives steam, water, or hot gases, primarily to heat the surrounding air, acts as a *radiator* of heat, and may be so called. But *radiators* built up into nests and having air drawn or forced between the different sections by propeller or fans, are called *heaters*, and are usually encased to ensure the actual contact of the heat with the radiating surfaces.

Heater Capacities.—The amount of heat which these heaters can emit to the air passing through them, depends on (1) the difference in temperature between the air and the hot surface; (2) the amount of the exposed surface; (3) the velocity of the air current; (4) the material of the heater pipes; and (5) the diameter of the heater pipes.

The greater the difference of temperature between the air and the hot surface, the higher the efficiency of the heater. When the cold air supply is lower the efficiency of the same temperature in the heater is higher, and hence helps up the deficiency and tends to equalise the resultant air.

As the heat has to be emitted from the surface, naturally

TABLE XII.—HEAT TRANSMISSION OF HOT-WATER PIPES, HEATED BODY OF CAST IRON.

Units of heat, emitted or absorbed, per square foot per hour.

Mean Temperature of Heated Body, Pipe, &c.	Temperature of Air and Walls.	UNITS OF HEAT PER SQUARE FOOT PER HOUR.				
		By Contact.		By Radiation.	By Radiation and Contact Combined.	
		Air Quiet.	Air Moving.		Air Quiet.	Air Moving.
70	70	0·00	0·00	0·00	0·00	0·00
80	70	5·04	8·40	7·43	12·47	15·83
90	70	11·84	19·73	15·31	27·15	35·04
100	70	19·53	32·55	23·47	43·00	56·02
110	70	27·86	46·43	31·93	59·79	78·36
120	70	36·66	61·10	40·82	77·48	101·92
130	70	45·90	76·50	50·00	95·90	126·50
140	70	55·51	92·52	59·63	115·14	152·15
150	70	65·45	109·18	69·69	135·14	178·87
160	70	75·68	126·13	80·19	155·87	206·32
170	70	86·18	143·30	91·12	177·30	234·42
180	70	96·93	161·55	102·50	199·43	264·05
190	70	107·90	179·83	114·45	222·35	294·28
200	70	119·13	198·55	127·00	246·13	325·55
210	70	130·49	217·48	139·96	270·49	357·48

—*F. Schumann.*

TABLE XIII.—HEAT TRANSMISSION OF STEAM PIPES, HEATED BODY OF CAST IRON.

Units of heat, emitted or absorbed, per square foot per hour.

Mean Temperature of Heated Body, Pipe, &c.	Temperature of Air and Walls.	UNITS OF HEAT PER SQUARE FOOT PER HOUR.				
		By Contact.		By Radiation.	By Radiation and Contact Combined.	
		Air Quiet.	Air Moving.		Air Quiet.	Air Moving.
210	70	130·49	217·48	139·96	270·49	357·48
220	70	142·20	237·00	155·27	297·47	392·27
230	70	153·95	256·58	169·56	323·51	426·14
240	70	165·90	279·83	184·58	350·48	464·41
250	70	178·00	296·66	200·18	378·18	496·84
260	70	189·90	316·50	214·36	404·26	530·86
270	70	202·70	337·83	233·42	436·12	571·25
280	70	215·30	358·85	251·21	466·51	610·06
290	70	228·55	380·91	267·73	496·28	648·64
300	70	240·85	401·41	279·12	519·97	680·53

—*F. Schumann.*

the amount will increase as does the amount of surface in contact.

The greater the velocity of the air against the surface the more heat it absorbs from the heater, but as the increased velocity decreases the efficiency of the fan and increases the power required to work the fan it is found from practice that 20 ft. per minute is the greatest economical speed. This speed may also be taken as the maximum inside the dryer.

Tables XII. and XIII. show the distribution of the heat and the resultant emission and absorption under different mean temperatures when still and moving.

For general purposes in calculating the radiation emission, it may be taken that it varies from 1·4 to 1·8 B.Th.U. per square foot of available surface per hour for each degree of difference between the incoming air and of the steam or water in the radiator or heater; for instance, with air at 60° Fahr. and steam in the radiator at 220°, every square foot of surface would emit per hour—

Cast-iron direct radiators - - -	256 B.Th.U.
Wrought-iron pipe (2 to 4 in.) - -	300 „
„ „ (1 to 2 in.) - -	350 „

Radiation Power.—The radiation power of the sections of these heaters is also dependent on the material of which they are constructed. It has been found by actual experiment that the number of units of heat emitted per hour per 1° Fahr. difference of temperature vary as follows:—

Copper - - - - - - -	0·0327
Sheet iron - - - - - -	0·092
Cast iron (new) - - - -	0·648
„ (rusted) - - - -	0·6868
Tin - - - - - - - -	0·0439
Glass - - - - - - -	0·5948

Diameters.—The *size of the pipes*, of course, affects the amount of surface per foot run, but it is found that the efficiency per square foot is greater in the smaller pipes. The following figures, although representing the actual B.Th.U. emitted under the specific condition of the air being at 60° Fahr. and the steam supply at 212° Fahr., also give a comparative guide for the respective size pipes:—

2-in. pipe - - - -	327 B.Th.U.
3 „ - - - -	303 „
4 „ - - - -	291 „
6 „ - - - -	279 „

Thus the smaller pipes show a considerably higher superficial area efficiency.

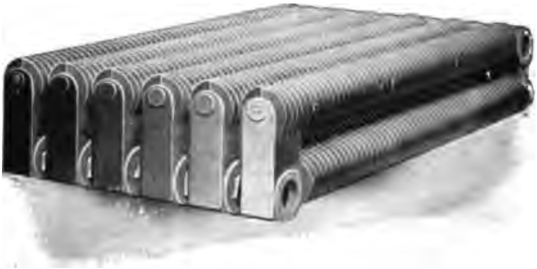

FIG. 37.—RIBBED TUBE HEATER.
(National Radiator Co., Ltd.)

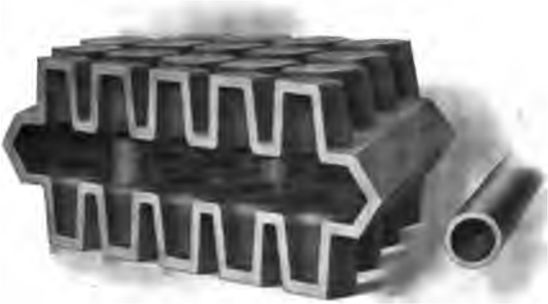

FIG. 38.—VENTO RADIATOR SECTION.
(National Radiator Co., Ltd.)

The sections of heaters are in all types designed to obtain the greatest possible surface. Fig. 37 shows a series of round *tubes* each having a number of parallel exterior ribs which, while avoiding the faults of the old-fashioned gilled pipes, greatly increase the convection. Fig. 38 gives a sectional perspective view of flat tubes which have prominent hollow bosses on each side to allow of hot air being used. Each of these is made of cast iron, and the sections can readily be assembled in large or small numbers according to the requirements, in the manner shown by Fig. 39.

The combined sections can then be built up into nests in such a manner as to ensure all air passing over the surface of each nest on the hit and miss plan.

Quite a different type of heater is the *Seagrave-Bevington* in which the surface is obtained through the inner surface of a number of small bore tubes. As shown in Fig. 40 these small bore tubes are expanded into the top and bottom wrought-iron plates of the heater body. Surrounding each of these small air tubes is a larger concentric steam tube, and these are expanded into the wrought plates of steam boxes shown at the top and bottom. These steam boxes have cast-iron frames and wrought top and bottom plates for connecting the tubes. It will thus be seen that when the heater is encased by steel covering air can be drawn through the small bore inner tubes and also between the larger outer tubes, thus obtaining the inner and outer

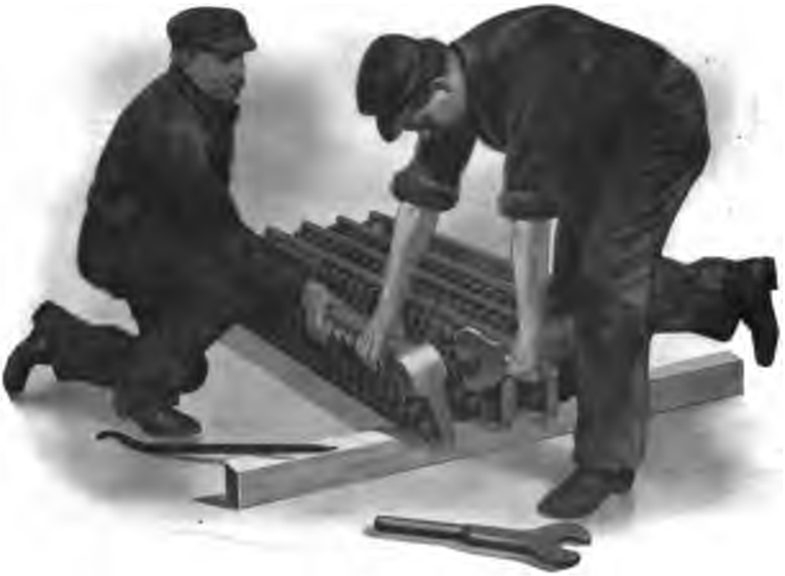

FIG. 39.—ASSEMBLING VENTO HEATERS.
(National Radiator Co., Ltd.)

surfaces of each annular steam unit. As illustrated it is specially designed for economical use of exhaust or live steam, and a modified form is suitable for direct fire heat when high temperatures are needed.

A compact complete heating plant for drying or ventilating purposes is the *Sturtevant Heater* shown in Fig. 41. Here is shown (1) a heater of their sectional base type with five sections fully cased in and connected up to (2) their steel plate exhaust fan with bottom horizontal discharge, and direct driven by (3) their vertical high speed enclosed engine; also (4) the pipes, valves, and connections to the automatic pump and receiver. The essential characteristic of the sectional base

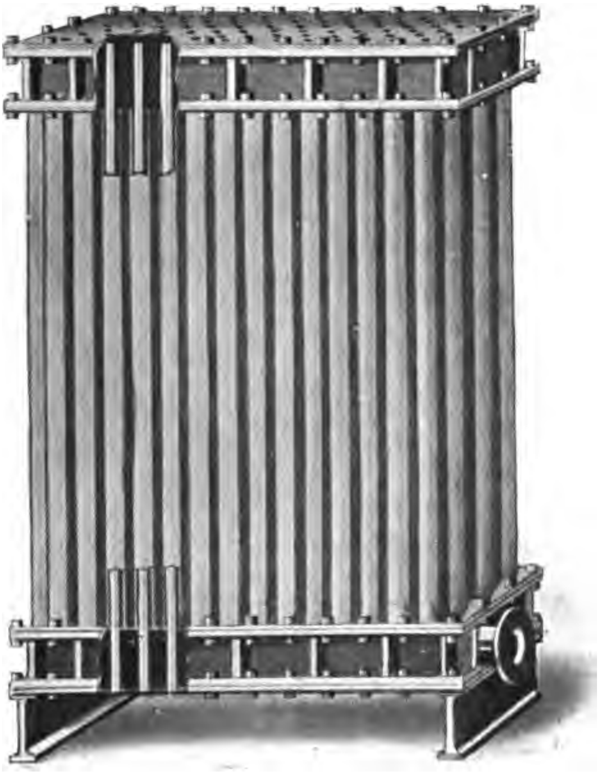

FIG. 40.—SEAGRAVE-BEVINGTON HEATER.
(W. J. Fraser & Co., Ltd.)

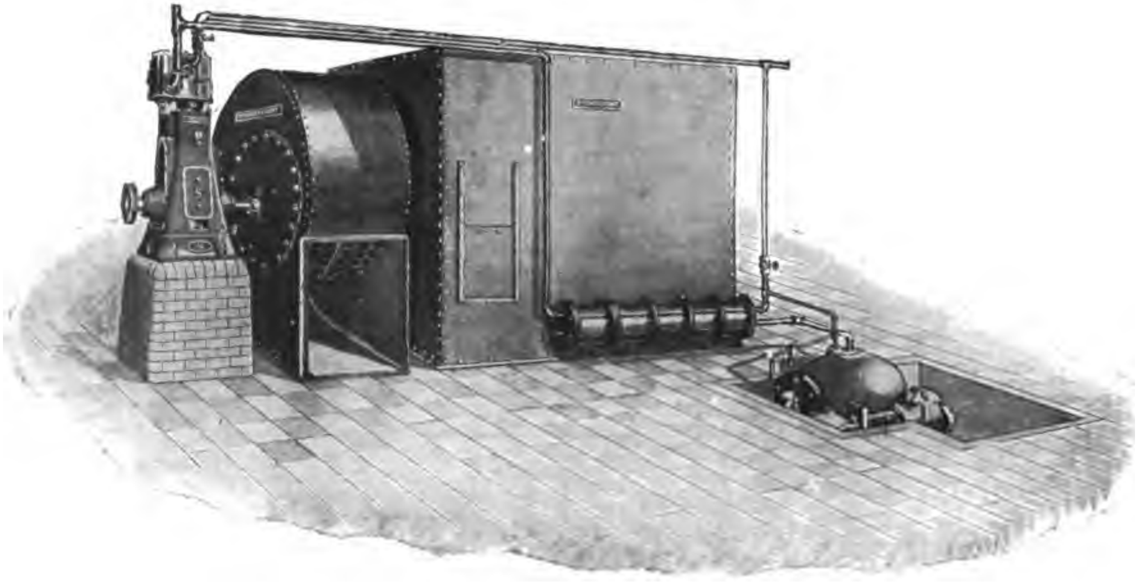

FIG. 41.—HEATING PLANT COMPLETE. GENERAL VIEW.
(Sturtevant Engineering Co., Ltd.)

heater is the combining in one base casting of the supply and return passages for the steam, and the use of wrought-iron tubes to connect the two divisions of the steam passages. As to the arrangement of the relative position of the heater and fan, it will be noticed that the air is drawn through the heater. The heated air is, of course, a larger volume to handle, and requires more power for the fan, but it thus increases the pressure under which the heated air is applied to the room or material which is the characteristic feature of the plenum process. This, of course, ensures more intimate contact and efficient warming of the room and material.

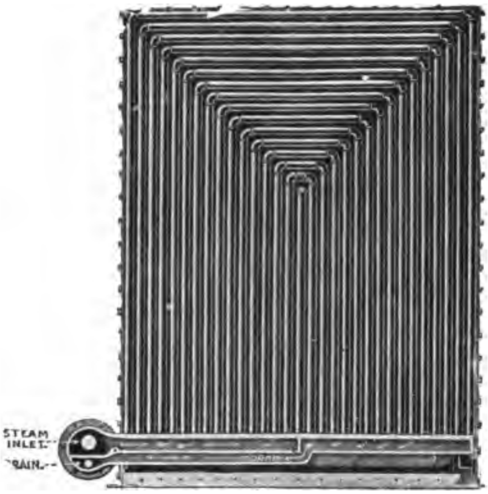

FIG. 42.—SECTIONAL BASE HEATER. SECTION.
(Sturtevant Engineering Co., Ltd.)

Fig. 42 shows in elevation and part section the construction of sectional base elements. The steam inlet and the condensed water outlet, to drain through steam trap, being in the one base casting for each element, while the steel steam pipes, being each connected into both divisions of the base, ensure a complete circuit for each portion of steam, and obtain the maximum amount of radiating surface. Fig. 43 shows the

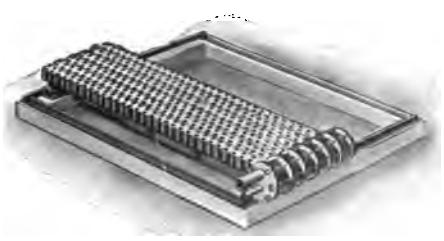

FIG. 43.—SECTIONAL BASE HEATER. IN BATTERY.
(Sturtevant Engineering Co., Ltd.)

method of assembling these base sections when of the flanged type for working in battery, and Fig. 44 shows the method where each section is treated as an independent unit with separate steam and drain connections. In each case both ends of the sections rest on angle irons which allow the base to expand and contract readily, while the vertical and horizontal arrangement of the pipes prevents the evils of unequal expansion on the joints. The corrugated form of the base lends itself to rigid assembling and economy of space.

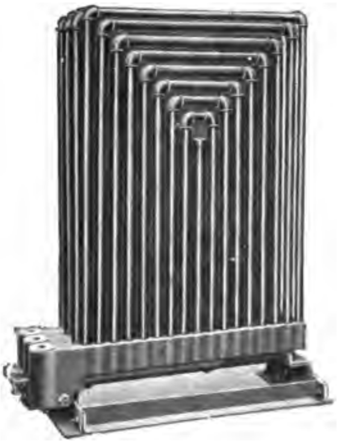

FIG. 44.—SECTIONAL BASE HEATER. INDEPENDENT UNITS.
(Sturtevant Engineering Co., Ltd.)

In Fig. 45 *Robinson's Tubular Heater* is illustrated by a plan and elevation *in situ*. As will be seen in the plan, the steam passes through a number of small bore pipes, which are enclosed in a casing of steel plate. The air is blown by a fan into this drum or casing, and is warmed by its contact with the hot pipes. This occurs in many tubular heaters of varying designs, but the distinguishing feature of Robinson's Heater is that the air is trained round and round the casing by means of a spiral plate. Thus the air is brought into repeated contact with the pipes instead of passing straight through as is usual. The efficiency is obviously much increased while the facility of using exhaust steam is considerably improved. The elevation, partly cut away, shows such a heater applied to drying clothes in twin rooms with open flooring and overhead outlet.

A *Tubular Flue Air Heater* has been designed to utilise the heat in flues which would otherwise pass away up the chimney. It consists of a number of small bore tubes placed over the main flue, and encased with a steel shell, through which a current of air may be drawn or blown, as with similar tubular heaters using steam. The smoke boxes at each end tend to prevent soot accumulations in the tubes, and all can be readily cleaned.

The heater is well suited to take advantage of the hot waste gases when these do not pass through an economiser for warming the supply water of the boiler, or to be placed between the economisers and the chimney.

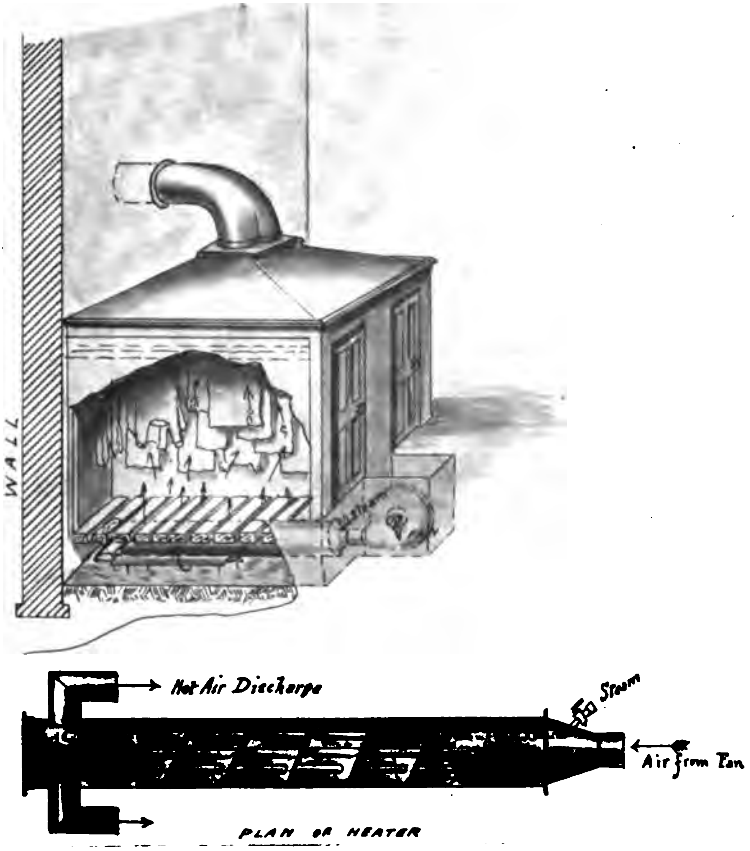

FIG. 45.—ROBINSON HEATER (PATENT) AND OVEN.
(J. J. Armfield & Co.)

Furnaces.

For drying, practically every type of furnace may be, and in one place or another is, used. The types of construction for various fuels and purposes are too great to be dealt with in a work on drying, especially as scarcely any are particularly designed with a primary view to drying.

The *Sirocco Multitubular Air Heater* (Fig. 46) is, however, a design special to drying machinery. The heater consists of a central furnace, from the back of which the products of combustion pass into the two upper smoke chambers at the right and left hand side of the furnace. From here they pass through the upper rows of tubes, arranged horizontally on each side of

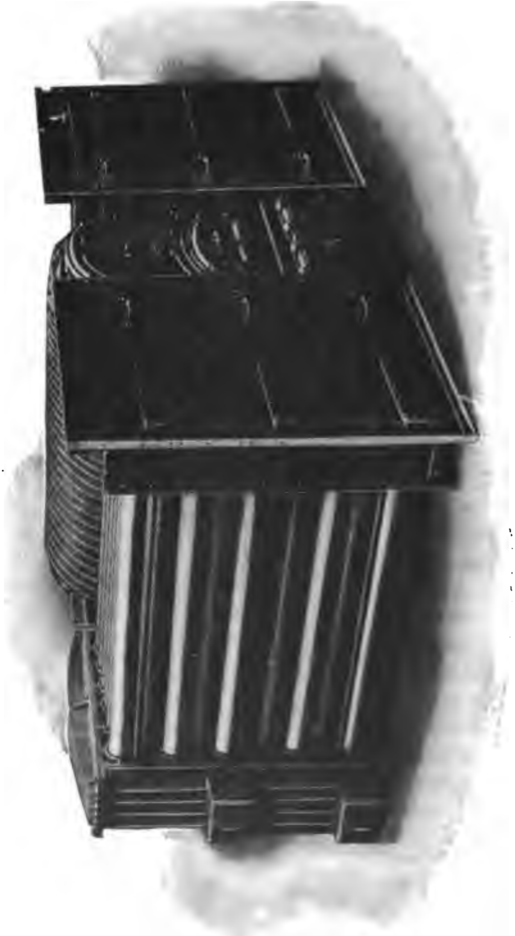

FIG. 46.—"SIROCCO" MULTITUBULAR AIR HEATER.

the furnace to the front smoke chambers. The gases then descend and pass through the lower row of tubes into the lower back smoke chambers which communicate with the base of the chimney. This long traverse gives ample time for the heat to be radiated through the tubes, the furnace shell, and the smoke boxes into the air currents which pass around them. When the whole furnace is cased in, as shown in Fig. 136 under Ovens, it forms an efficient means of heating large volumes of air by direct firing, without any risk of contamination by smuts and the products of combustion.

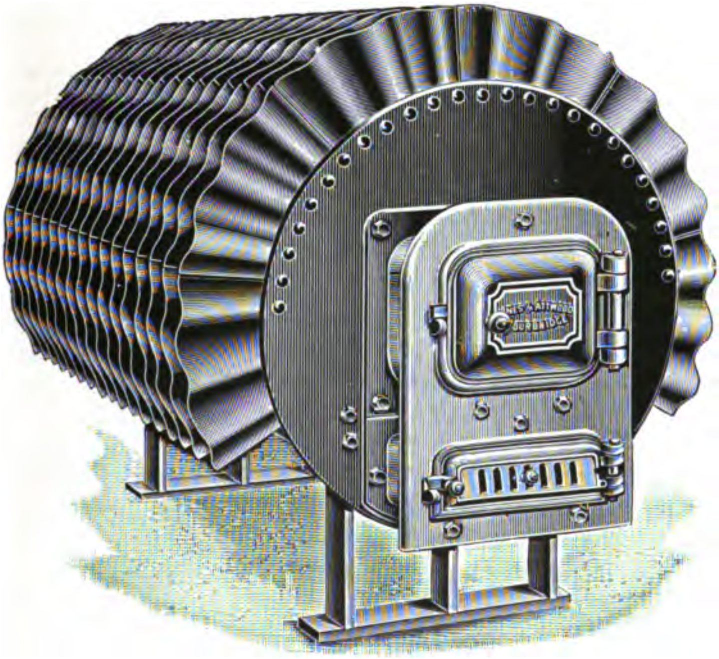

FIG. 47.—SHEW'S (PATENT) ECONOMIC FURNACE.
(Jones & Attwood, Ltd.)

Shew's (*Patent*) *Economic Furnace*, illustrated by general view in Fig. 47, is a hot air furnace, especially designed for drying purposes. The combustion chamber is entirely enclosed by a stout, many gilled body, which allows of an intense heat without any product of combustion coming in contact with the heated air. The neck on the front of the grate allows of it being built into an exterior wall, so that the stoking can be done from outside. The gilled radiating surface can be open to a brick room or encased with metalwork to concentrate its heat. The flue passes straight through and out at the back of the furnace to conduct the smoke, &c., away. While first applied to hop kilns in converting them into hop drying-rooms, it is applicable for other hot air supply to rooms, tunnels, or ovens. The grate and ash doors shown are suitable for coal, coke, &c., but can be adopted to other fuels.

For further Drying Furnaces see Figs. 87, 96, 140, 142, &c.

Flues and Ducts.

Flues.—The flues in connection with the furnaces and steam generators for drying are similar in most respects to those used in other steam plants, and need not be detailed here. In connection with direct fired drying floors and drying pans, the flues are generally divided into a number of comparatively small ones, in order to distribute the heat over the floor or pan as evenly as possible. In these cases, too, they generally extend the full length of the floor or pan, and the vertical flue or chimney is at the far end from the fires. The bottom of the flue is generally of sand, as a bad conductor (see p. 104). In some drying ovens the flues are of metal, as being good conductors, so that they radiate off their heat to the air surrounding them (see Fig. 128 and p. 223).

In the cylinder dryers the dryer proper forms the main flue, and receives all the products of combustion (see Fig. 93, p. 184). But in others the flue surrounds the cylinder and heats the material through the substance of the cylinder (see Fig. 96, p. 185). In kilns and some stoves, too, flues are not necessary as the material is so placed as to allow the hot gases and products of combustion to pass through or between them into the outlet cowl or vent.

TABLE XIV.—EQUALISATION OF PIPE DIAMETERS.

This table shows the relation of the combined area of small round warm air ducts or pipes to the area of one large main duct.

The bold figures at the top of the column represent the diameters of the small pipes or ducts; those in the left-hand vertical column are the diameters of the main pipes. The small figures show the number of small pipes that each main duct will supply.

EXAMPLE. — To supply sixteen 10-inch pipes: Refer to column having 10 at the top; follow down to small figure 16, thence left on the horizontal line of the bold-face figure in the outside column, and we find that one 30-inch main will supply air for the sixteen 10-inch pipes.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1																														
2	5·7																													
3	16	2·7																												
4	32	5·7	2·3																											
5	56	9·7	3·6	1·8																										
6	88	16	5·7	2·8	1·6																									
7	129	23	8·3	4·1	2·3	1·5																								
8	180	32	12	5·7	3·2	2·1	1·4																							
9	244	42	16	7·6	4·3	2·8	1·9	1·3																						
10	317	56	20	9·9	5·7	3·6	2·4	1·7	1·3																					
11	402	71	26	12	7·0	4·5	3·1	2·2	1·7	1·3																				
12	501	88	32	16	9·0	5·7	3·8	2·8	2·0	1·6	1·2																			
13	613	107	39	19	11	6·9	4·7	3·4	2·5	1·9	1·5	1·2																		
14	737	129	47	23	13	8·3	5·7	4·1	3·0	2·3	1·8	1·5	1·2																	
15	876	152	56	27	16	9·9	6·7	4·8	3·6	2·8	2·2	1·8	1·4	1·2																
16	1026	180	65	32	18	11	7·9	5·7	4·2	3·2	2·6	2·1	1·7	1·4	1·2															
17	1197	208	76	37	21	13	9·2	6·6	4·9	3·8	2·9	2·4	2·0	1·6	1·4	1·2														
18	1375	239	88	43	24	16	10	7·7	5·7	4·3	3·4	2·8	2·3	1·9	1·6	1·3	1·2													
19	1580	275	100	49	28	18	12	8·8	6·5	5·0	3·9	3·2	2·6	2·2	1·8	1·5	1·3	1·2												
20	1775	312	114	56	32	20	14	9·9	7·4	5·7	4·5	3·6	2·9	2·5	2·1	1·7	1·5	1·3	1·1											
21	1985	345	130	61	35	22	15	10	8·4	6·3	5·2	4·1	3·2	2·6	2·3	2·0	1·6	1·4	1·2	1·1										
22	2250	398	145	71	41	26	18	13	9·3	7·2	5·7	4·5	3·7	3·1	2·6	2·2	1·9	1·7	1·4	1·3	1·1									
23	2525	460	160	77	47	29	20	14	10	7·8	6·2	5·0	4·1	3·4	2·8	2·4	2·1	1·8	1·6	1·4	1·2	1·1								
24	2800	493	180	88	50	32	22	16	12	8·9	7·6	5·7	4·6	3·8	3·2	2·9	2·4	2·1	1·8	1·6	1·3	1·2	1·1							
25	3060	543	202	97	55	35	24	17	13	10	8·0	6·4	5·2	4·2	3·5	3·1	2·6	2·2	2·0	1·7	1·5	1·3	1·2	1·1						
26	3425	590	219	108	62	39	27	19	14	11	8·6	6·9	5·7	4·7	4·0	3·4	2·9	2·5	2·2	1·9	1·7	1·5	1·3	1·2	1·1					
27	3738	677	243	121	68	43	29	21	15	12	9·6	7·5	6·1	5·1	4·3	3·6	3·1	2·7	2·4	2·1	1·9	1·6	1·5	1·3	1·2	1·1				
28	4100	725	265	129	74	48	32	23	17	13	10	8·3	6·8	5·7	4·8	4·1	3·5	3·0	2·6	2·3	2·1	1·8	1·6	1·5	1·3	1·2	1·1			
29	4440	800	289	141	79	52	35	25	19	14	11	9·1	7·5	6·2	5·2	4·4	3·8	3·3	2·9	2·5	2·2	2·0	1·8	1·6	1·4	1·3	1·2	1·1		
30	4898	864	315	151	88	56	38	28	20	16	12	9·9	8·0	6·7	5·7	4·7	4·1	3·6	3·0	2·6	2·4	2·2	1·9	1·7	1·5	1·4	1·3	1·2	1·1	
31	5312	920	344	168	96	59	40	30	22	17	13	10	8·9	7·4	6·1	5·1	4·5	3·9	3·4	3·0	2·7	2·4	2·1	1·9	1·7	1·5	1·4	1·3	1·2	1·1
32	5631	1070	374	184	103	63	42	32	23	18	14	11	9·3	8·0	6·5	5·7	4·8	4·2	3·7	3·2	2·8	2·5	2·3	2·0	1·8	1·6	1·5	1·4	1·3	1·1
33	6154	1140	401	196	109	70	45	35	25	19	15	12	10	8·5	7·1	6·0	5·2	4·4	3·9	3·5	3·0	2·7	2·4	2·2	2·0	1·8	1·6	1·5	1·3	1·2
34	6675	1208	433	212	119	76	51	37	27	21	16	13	11	9·1	7·6	6·4	5·5	4·8	4·2	3·7	3·3	2·9	2·6	2·4	2·1	1·9	1·7	1·6	1·5	1·3
35	7075	1280	470	229	127	82	56	40	30	23	18	14	12	10	8·4	7·1	6·1	5·3	4·6	4·0	3·5	3·1	2·8	2·5	2·3	2·1	1·9	1·7	1·5	1·4
36	7735	1355	497	242	138	88	60	43	32	25	19	16	13	11	8·9	7·6	6·5	5·7	5·0	4·3	3·7	3·4	3·0	2·7	2·4	2·2	2·0	1·9	1·7	1·6
37	8265	1435	537	260	146	94	64	45	33	26	20	16	13	11	9·3	7·9	6·9	6·0	5·3	4·6	4·0	3·6	3·2	2·9	2·6	2·3	2·1	1·9	1·8	1·6
38	8715	1625	575	279	157	100	68	49	37	29	22	18	14	12	10	8·6	7·4	6·3	5·5	4·8	4·3	3·8	3·4	3·1	2·8	2·5	2·3	2·1	1·9	1·8

Ducts.—Ducts for hot and cold air are of great importance in connection with drying. As they are sources of loss in heat by radiation, and of power by the friction of the air against their sides, they are to be avoided where possible. And where in distributing it is necessary to subdivide, it should be by carefully equalised capacities, for which Table XIV. is of great use.

In all air ducts abrupt angles should be avoided, and blank ends quite debarred. All turns should be by curves at a good sweep, and as few turns as possible, even when gradual. In all cases it is expedient to test each branch by the syphon gauge to see whether it is obtaining its calculated current. This can readily be checked by the Table XV. of *Syphon pressure draft gauge*.

TABLE XV.—SYPHON PRESSURE DRAFT GAUGE.

Height Water, Inches.	Pressure per Lb.	Velocity, Feet per Sec.	Velocity, Feet per Min.	Height Water, Inches.	Pressure per Lb.	Velocity, Feet per Sec.	Velocity, Feet per Min.
0·1	0·521	15·05	903	1·1	5·731	49·9	2,949
0·2	1·042	21·3	1,278	1·2	6·252	52·1	3,126
0·3	1·563	26·06	1,564	1·3	6·773	54·2	3,252
0·4	2·084	30·1	1,806	1·4	7·294	56·3	3,378
0·5	2·605	33·6	2,016	1·5	7·815	58·2	3,492
0·6	3·126	36.8	2,208	1·6	8·336	60·2	3,612
0·7	3·647	39·8	2,388	1·7	8·857	62·0	3,720
0·8	4·168	42·5	2,550	1·8	9·378	63·8	3,828
0·9	4·689	45·1	2,706	1·9	9·899	65·6	3,936
1·0	5·210	47·5	2,850	2·0	10·420	67·3	4,038

This gauge, which is illustrated in the standard form by Fig. 48, consists of a syphon with a socket connection. The syphon generally contains water when the readings on the gauge are actual, but sometimes a lighter liquid such as petroleum is used. Then the readings are more sensitive, and can be reduced to water scale. When connected to the air duct or flue, the difference in pressure at once causes a movement in the syphon corresponding to the aspiration of the air. As the velocity is dependent on this difference of pressure, it can readily be calculated as shown in Table XV. This table also gives the pressure in pounds per square inch of surface for comparison. The gauge, besides the special joints for easy renewal and cleaning, also has a needle valve shown in the base to simplify the adjustment of the water column to zero of the scale. It will be advisable in all cases of importance to put a valve in the duct to enable the capacity to be equalised or varied if found expedient on testing.

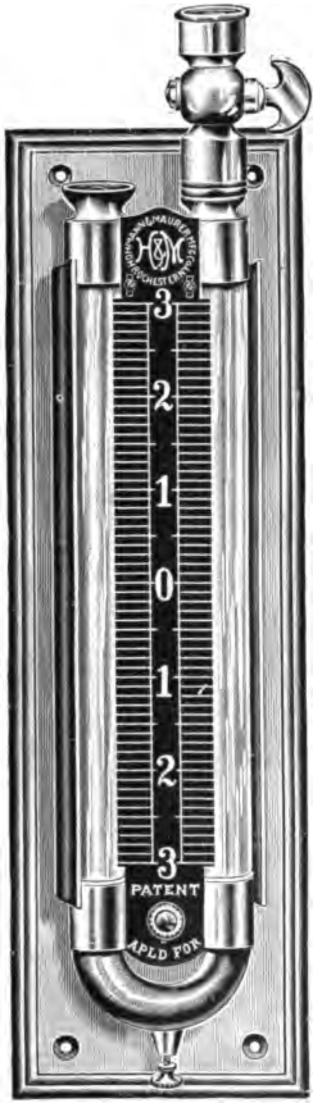

FIG. 48.—SYPHON PRESSURE DRAFT GAUGE.

(Cambridge Scientific Instrument Co., Ltd.)

Examples.—Many plants for drying by hot air are so designed as not to need any ducts; for instance, the one shown in Fig. 42 working on the plenum system does not necessarily need any ducts if placed in or near the drying-room or oven. Fig. 49 illustrates an application of a heater to two rooms alternately, so arranged that only one valve and no ducts are required. In this case the air propeller is used to force the air through the heater and so has less volume of air to transmit, the air being in a denser and cooler con-

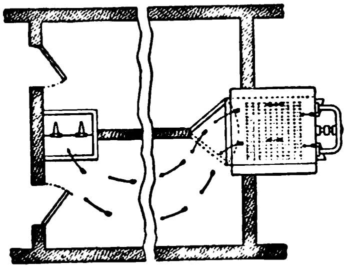

FIG. 49.—TWIN DRYING-ROOMS.

(National Radiator Co., Ltd.

dition. The heated air is supplied under the plenum, created by the fan pressure and the expansion of the air from the heat.

The heater shown in Fig. 50 is a yet simpler arrangement, having no fan or propeller, yet supplying heated air either for drying or ventilating under slight plenum with aeration. The inlet and outlet ducts shown could be dispensed with and still obtain nearly the same efficiency.

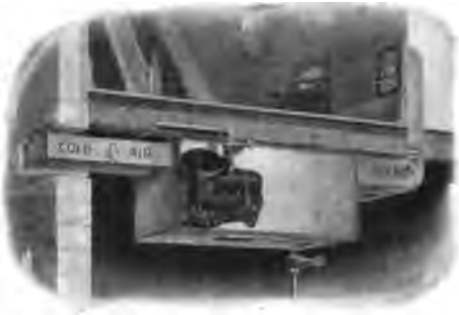

FIG. 50.—AERATION HEATER WITH DUCTS.
(National Radiator Co., Ltd.)

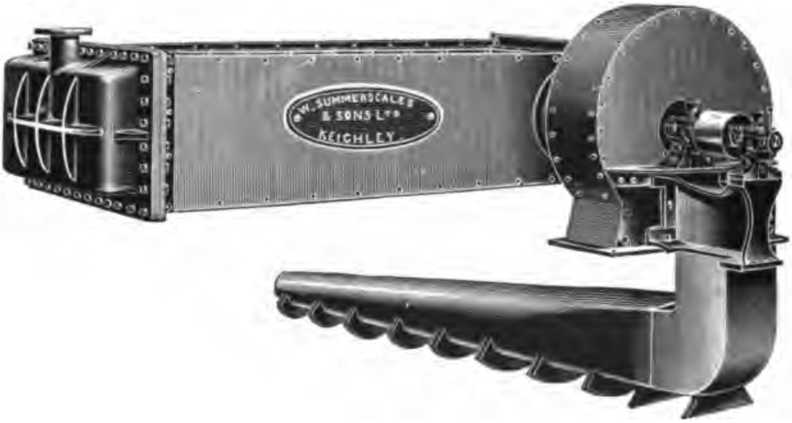

FIG. 51.—DISTRIBUTION EQUALISER WITH FAN AND HEATER.
(W. Summerscales & Sons, Ltd.)

Ducts are also useful in regulating the temperature of the air currents, and by means of suitable valves allow a very wide range of adjustment as will be readily seen, giving accommodation for supplying under the full force of the fan either cold air only, or hot air only, or any graduation between the two extremes, simply by altering the valves without any stoppage of the fan or the heater.

Where the drying oven is subdivided by frames or gantries as in laundry ovens, the duct shown in Fig. 51 forms a means of giving an *equalised distribution* in each portion of the oven or compartment, and thus ensuring the most intimate contact with the surface of the materials or goods to be dried.

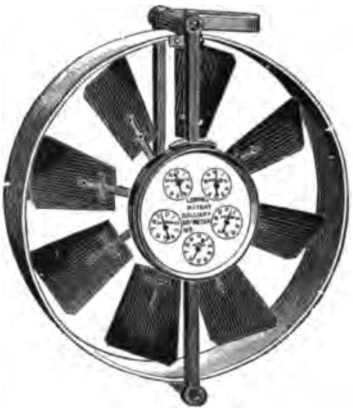

FIG. 52.—BIRAM'S AIR METER.
(Negretti & Zambra.)

The regulation of equal currents in two or more ducts from a common source is not a simple matter, and it is advisable in working to test each duct. For this purpose *Biram's Air Meter*, shown in Fig. 52, is a very handy form made specially for inserting in any part of a duct. The vanes and works are so constructed as to prevent injury and ensure accuracy, being dust-tight and anticorrosive. The dials register up to 100,000 ft., and by means of the catch over the gear can be stopped and started when in position. The principle is the same as that described on page 66, but adapted in form to its special purpose.

A special *louvred duct* or series of small ducts applied in leading the heated air in a number of distributed jets through the moving mass of grain or similar granular material is shown in Fig. 53. The air chamber is entirely surrounded by the double casing of which a portion is shown, the inner casing being of metal louvres and the outer of perforated metal. Between the two the grain falls by gravitation, and as the chamber is of considerable height it is warmed and dried during its passage through this stream of heated air. The fall of the grain is regulated by the valve at the foot, which only permits a given quantity to be delivered by the roller.

Heat Losses.

How and Where they Arise.—Every transfer of heat from the furnace or source where it is generated causes a loss in the available portion for actual work. Thus in the furnace some of the heat energy is absorbed or lost in warming the fuel, the bars and the flues must be heated to the temperature of the escaping gases. In kilns, stoves, and direct fired cylinders, floors, and pans, part of the heat is used for heating their structures and replacing their losses by radiation; these vary greatly according to their structure, leaving the whole of the remainder available for heating the material and evaporating the moisture. Hence kilns, stoves, and direct fired cylinders, floors, and pans, should, if well

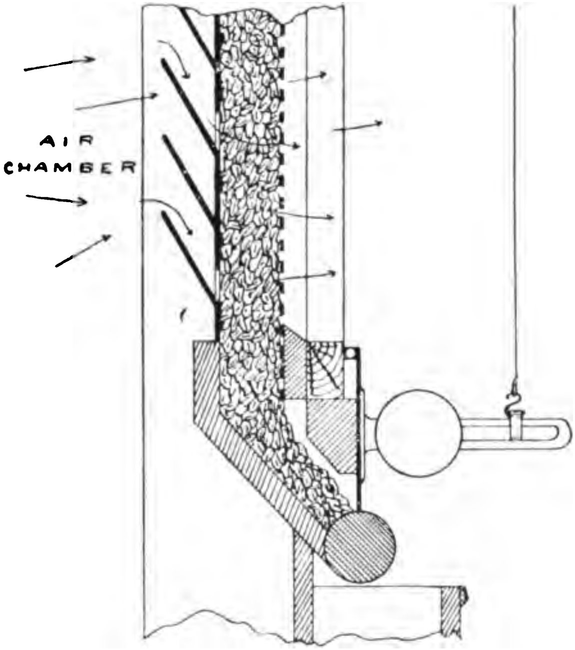

FIG. 53.—LOUVRED GRAIN DRYER.
(Higginbottom & Co., Ltd.)

constructed, be economical of fuel so far as the actual transmission of the heat to the material is concerned. In the case of floors and pans the radiation, however, is found in practice to be a considerable loss. All furnaces demand the necessary heat to convey away the waste gases, and the difference between their temperature and that of the air and fuel before they entered the fire.

In dealing with drying by hot air, hot water, and steam, there are further losses of heat at each stage of their transmission. The boiler, the pipes, the valves, and the heater, all claim their quota in heating their constructive materials and for the radiation from their surfaces.

Having the air heated and delivered at the highest temperature the nature of the material to be dried permits of, there are further losses to be considered before the air can perform its purpose of drying to the best advantage. The room, oven, tunnel, chamber, compartment or receptacle has to be heated and maintained heated against losses by radiation. The actual warming of the room, &c., is of small amount, and can generally be ignored, but the radiation losses vary greatly and must be fully considered in every economical drying plant. This loss will depend on the extent and nature of the exposed parts of the rooms. They can be calculated in B.Th.U. per hour according to the difference in temperature between the inner and outer sides of the walls of the structure by the coefficients of transmission as given in Table XVI. Further provision must be allowed for special conditions such as exposure, or bad construction of doors and windows.

After allowing for all these losses of generation and transmission, the heated air being in contact with wet material is subject to the task of *heating this material*, and the amount of loss from this cause will depend on the specific heat of the material (see Table III.) and the difference of temperature between the material as placed in the dryer and when dried.

A further considerable loss during the vaporisation arises from the fact that the vapour is removed in nearly all cases *superheated* or having more heat than essential for its density. This is one of the losses which the various types of dryers especially aim at eliminating so far as economically practicable, but full saturation is seldom obtained and never economical.

TABLE XVI.—HEAT TRANSMISSION LOSSES.

External temp., Fahr.	45	40	35	30	25	20	15	Co-efficient,
Internal temp., "	60	60	60	60	60	60	60	
Temp. difference, "	15	20	25	30	35	40	45	1
Multipliers for—								
4½-in. brick wall -	7·5	10	12·5	15	17·5	20	22·5	·5
9 " " -	5·25	7	8·75	10·5	12·25	14	15·75	·35
14 " " -	4·05	5·4	6·75	8·1	9·45	10·8	12·15	·27
18 " " -	3·45	4·6	5·75	6·9	8·05	9·2	10·35	·23
22 " " -	3	4	5	6	7	8	9	·2
26 " " -	2·7	3·6	4·5	5·4	6·3	7·2	8·1	·18
Single windows -	15·45	20 6	25·7	30·9	36·05	41·2	46·35	1·03
Double " -	7·5	10	12·5	15	17·5	20	22·5	·48
Single skylights -	16·65	22·2	27·75	33·3	38·85	44·4	49·95	1·11
Double " -	7·5	10	12·5	15	17·5	20	22·5	·5
Corrugated iron roof -	32·55	43·4	54·25	65·1	75·95	86·8	97·65	2·17
Ceiling close to roof -	4·8	6·4	8	9·6	11·2	12·8	14·4	·32
Ceiling, with good air space - - -	1·95	2·6	3·25	3·9	4·55	5·2	5·85	·13
Floor, 12 in. concrete and wood - -	2·55	3·4	4·25	5·1	5·95	6·8	7·65	·17
Floor, wood on joists -	7·8	10·4	13	15·6	18·2	20·8	23·4	·52
Doors, 1½ in. thick -	6·75	9	11·25	13·5	15·75	18	20·25	·45

The actual heat available for evaporating the water and thus drying the material must eventually amount to sufficient quantity to supply the latent heat to vaporise the water, and the sensible heat to raise the temperature of the vapour to that of the air at the point of exit. The latent heat is thus a still further apparent loss, but only apparently so. If the vapour were cooled back to water at the primary temperature it would emit the latent heat as well as the sensible in the operation; whereas all the other losses are so much thermal energy used up in extraneous directions, and could not be made available by any condensation of the vapour back to water. The quantity of heat which would thus be emitted really represents the total heat absorbed by the water, and can readily be calculated by the following formula, where

B_d = the heat of 1 lb. of the vapour in B.Th.U.,
Ta = temperature in Fahr. deg. of the wet material,
T_d = " " " aqueous vapour,
L_d = latent heat in B.Th.U.

$$\text{Then } B_d = (T_d - Ta) + L_d$$
$$= (T_d - Ta) + 966 - {\cdot}71(Ta - 212^\circ).$$

In other words, the total heat will equal the difference in temperature or sensible heat $(T_d - Ta)$ plus the heat of evaporation or latent (L_d) heat, as shown in the Table X.

Insulation.

Insulation.—The losses of heat arising from transmission in the ducts and drying-rooms, while not so vital as in the case of steam pipes, are yet always a point for consideration, and in many cases of great importance. Hence insulation is desirable from an economical point of view. The illustrated types (Fig. 54) of built-up insulation are essentially suitable where the drying-

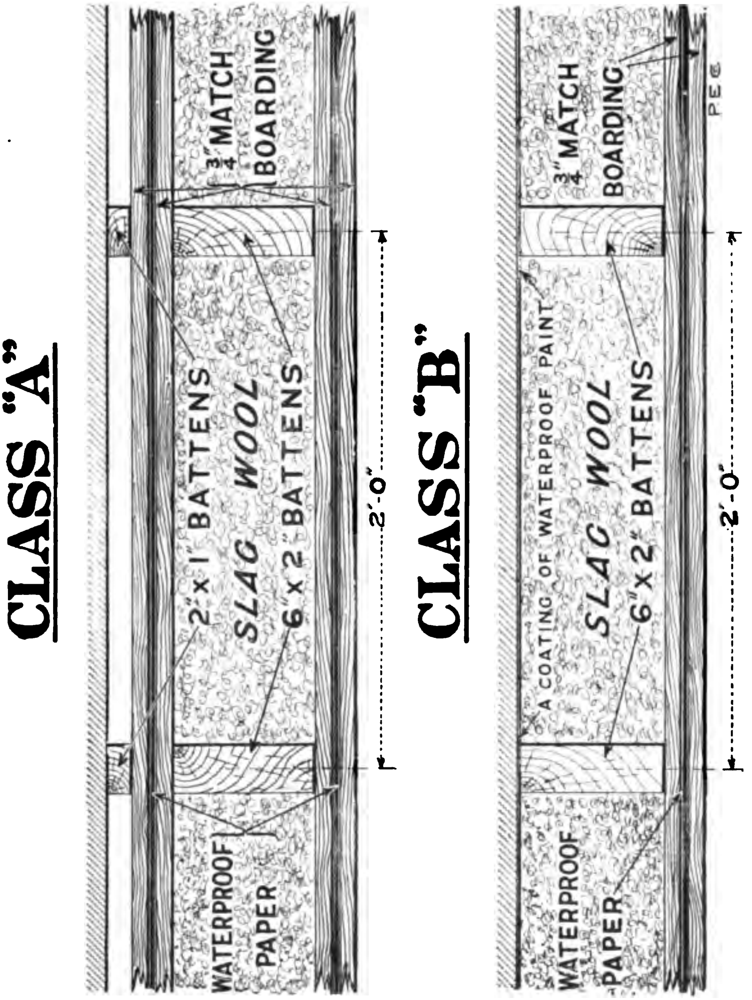

FIG. 54.—INSULATION FOR HEAT. SECTIONS.
(Pulsometer Engineering Co., Ltd.)

rooms or ovens are exposed, especially when working at slight variations of the air pressure whether above or below normal. Slag wool is shown as being really the best non-combustible covering, and in drying apparatus its brittle nature does not count, vibration or jar not being present. The fine hair-like capillary fibres lace and interlace each other in every direction, forming numberless minute air cells containing "still air," which is recognised as the best non-conductor. The advantages of Class A construction over that of Class B well cover the extra expense in dealing with high or low temperatures, but for ordinary drying purposes Class B is ample.

Non-Conductors.—The wide difference in the values of non-conductors is shown by the Table XVII. of insulating values quoted from *Steam.* Although air is a bad conductor its fluidity causes it, when undivided, even though confined, to readily convey the heat and dissipate it by convection, but where the air is held as "still air" in the minute air cells of other materials it greatly increases their insulating value.

TABLE XVII.—INSULATING VALUES.

Substance.	Value.	Substance.	Value.
*Loose wool	3·35	Loam, dry and open	·55
*Loose lampblack	1·12	Chalk, ground, Spanish white	·51
*Geese feathers	1·08	Coal ashes	·35 to ·49
*Felt, hair, or wool	1·	Gas-house carbon	·47
*Carded cotton	1·	Asbestos paper	·47
*Charcoal from cork	·87	Paste of fossil meal and asbestos	·47
Mineral wool	·68 to ·83	Asbestos, fibrous	·36
Fossil meal	·66 to ·79	Plaster of Paris, dry	·34
*Straw rope, wound spirally	·77	Clay, with vegetable fibre	·31
*Rice chaff, loose	·76	Anthracite coal, powdered	·29
Carbonate magnesia	·67 to ·76	Coke, in lumps	·27
*Charcoal from wood	·63 to ·75	Air space, undivided	·14 to ·22
*Paper	·50 to ·74	Sand	·17
*Cork	·71	Baked clay, brick	·07
*Sawdust	·61 to ·68	Glass	·05
Paste of fossil meal and hair	·63	Stone	·02
Wood ashes	·61		
*Wood, across grain	·40 to ·55		

—*Steam.*

* Combustible, and sometimes dangerous.

In direct fired drying plants the insulation is generally of fire-brick cemented by gannister and supported by thick layers of brick or stone work, while at the top and bottom sand is used because of its cheapness and in goodly quantities to compensate for its comparatively poor efficiency.

Some of the stoves and cylinder dryers are lagged and then covered with bright tin or steel plates which are very efficient, being also used on portable engines for the same purpose.

Dangers.

The dangers from drying are due to (1) the nature of the material to be dried, (2) the different action the same quantity of heat has upon the material when applied in varying periods of time, (3) the differing power of heat absorption of the same material, when wet and when dry, (4) the uncertainty of the amount of moisture in the wet material, (5) the uneven or partial application of the heat, and (6) the vaporisation being from the surface and not evenly throughout the mass.

Nature of the Material.—As drying is required more or less in or on all solids and semi-solid substances and goods, their varying natures offer many very wide and interesting problems. On the one extreme there is granite or limestone chippings to dry for asphalting, on the other, silk and woollen fabrics after dyeing. In many cases the danger is so obvious as to be less a danger, but many of these characteristic dangers can only be learnt from experience. For while light is generally an assistance to drying and a benefit to the material which has to be dried, there are materials such as leather and rubber in which light is objectionable and direct light injurious.

Time Problem.—The time problem is also one needing actual experience or careful experiment. While it is necessary to apply a fixed quantity of heat energy to vaporise a fixed quantity of water, and this quantity of heat can be applied without injury to the material in due time; but if the heat be applied quicker than the material accommodates itself to the modified conditions, injury is bound to result. For instance, wet bricks or pottery will crack and warp if heat is applied in any way but slowly and evenly until a very large percentage of their water is evaporated, while intense heats afterwards are beneficial. Lumber drying is specially beset with these dangers, for the resin and albumen of the sap are readily hardened by heat. Thus if heat be applied too quickly the resins and albumens near the surface harden and close up the pores, thus "checking" the vaporisation of the interior moisture. On further heat being applied they expand and cause cracking, while the albumens not being withdrawn from the interior set up the fermentation and initiate the decay that the drying when properly carried out entirely prevents.

Wet and Dry.—A material while in the wet state is usually of much greater heat capacity, because of the capacity of its moisture, also because its pores have not the air in them which make a large difference to their conductivity. In batch drying or where there is not a good body of air to absorb the heat, and so prevent any quick changes of temperatures for small increase of added heat, this is a danger to any sensitive material. In drying by actual contact with heated pipes or metal in the open air, but more especially in stoves, there should be careful and adequate provision for an abundant air current, or for instant withdrawal of the dried product. If a material is to be partially dried and removed while part of the moisture still remains throughout its mass, a higher degree of temperature can be safely applied. While when drying by heated air, if the material has to be thoroughly dried, the temperature of the heated air should never exceed that suitable for the dried state of the material.

Degree of Dryness.—If the exact amount of moisture in a wet material were known, it would often be possible to apply more intense, and therefore more economical, heats, as the time for drying could then be calculated and a time safeguard put to regulate the heat supply. The impracticability of measuring the moisture quite prevents this being possible in regard to any sensitive material, the only safe course being to work at temperatures considerably under the critical one for each particular material when in its dry state.

Local Application.—The uneven or local application of the heat causes distortion and cracks in many articles owing to the fact that nearly all materials shrink as they dry. This shrinking, being local instead of uniform, causes the damage. This is often conspicuous in sun-dried substances, as the radiant heat is so much more powerful than that in the air and than the cold ground. It points to the advisability of all wet materials being kept from contact with the source of heat, or if in contact as in the cylinder dryers, then they should be agitated to get every point equally often in contact. The warping of wood when not evenly exposed to the air is thus caused, and the result shows the power with which dried materials shrink.

Even when the heat is carefully adjusted in temperature its even distribution in the drying chamber is of considerable importance, especially in the case of thermally sensitive goods, such as rubber, claywares, &c., and draughts are to be avoided. There is also the consideration of obtaining an equally dried sample throughout the batch or bulk. Various arrangements of louvres and divided shoots are used to ensure this. The Equalising Chambers illustrated in Fig. 96 for cylinders, Fig. 133 for rooms, and Fig. 171 for autoclaves are cases in point. The Distribution Equaliser, shown in Fig. 51, also aims at this desirable end, while there have just been placed on the market Tapair Sprays, which are specially formed double tapered air passages to ensure an even distribution under high or low pressure without local eddies or draughts.

Practically all evaporation is from the surface, and the drying of the mass is a gradual process of equalisation dependent very largely on the nature of the material. If the material can be moved or agitated so that each particle comes repeatedly to the surface, then the speed can be greatly accelerated, but where the mass is dense or the inner portions are inaccessible, the aim should be as far as practicable to apply heat only so fast as it can be conducted by the material. This is the great advantage of gantries for drying and the great disadvantage of floors heated from above. With floors heated from below, the danger is from a cooking or "caking" operation followed by the uneven sample produced.

CHAPTER VI

METHODS OF REMOVING THE VAPOUR

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General Considerations.—While the time problem is of considerable importance in applying the heat to vaporise the water, the removal of the vapour cannot be too rapid. Time is required between the application of the heat and the actual vaporisation. But the vapour forms an atmosphere and pressure of its own which increasingly tends to retard or prevent further vaporisation as saturation is approached. Hence the more quickly the vapour is removed the more speedy will be the vaporisation at the same temperature.

Nature's way of removing this vapour is by air currents, and artificial drying is only an acceleration of this method, except in the case of the vacuum process. [In the vacuum process the air is practically eliminated from the dryer receptacle, and the vapour pumped out as formed (see page 111).] The air current, whether natural or mechanically produced, mingles with the vapour, and carries it along with itself. The vapour is at all temperatures very attenuated as compared with air. At low temperatures this is the more marked; for instance, as will be seen from Table VI., at 32° Fahr. vapour is ·000304 lb. as compared with air, ·0807 lb., per cubic foot. Although the vapour increases in density and weight as the temperature rises, still at 212° Fahr. the vapour weighs ·03682 lb. as compared to air, ·0591 lb., per cubic foot, and it will be noticed that it has then practically expelled the air from the saturated mixture. With this small amount of vapour when saturated it becomes at once apparent that the volume of air to be moved will be great, and if the air be not saturated the volume required will be increased proportionately, hence for efficiency the air should be well burdened. To obtain any considerable degree of saturation, however, takes *time*, and this limits the velocity at which air can be economically utilised for drying. If it be advisable to accelerate the drying, and it is to be done economically by air, then the volume must be increased while retaining the same velocity and temperature. This is quite independent of the fact that the air may or may not at the same time be the medium for conveying the heat to the material.

Systems of Vapour Removal.—The air is in contact with everything which has to be dried, so whether it be used as a medium in the process of drying or not, it has in any case to be moved before drying can be perfected. Various methods are used for removing the air and the commingled vapour. These methods may be divided according to their principles of operation into—

(1) *Aeration Process*, where the air movements are caused by the difference in weight between the warm and cold air.

(2) *Exhaust Process*, where the air movements are assisted more or less from the drying space by mechanical means.

(3) *Vacuum Process*, where the air is withdrawn from the drying space and vaporisation proceeds under a vacuum.

(4) *Plenum Process*, where the air movements are controlled by the addition of a superabundance of air to the drying space by mechanical means, usually a fan.

(5) *Compression Process*, where the air is pressed out by a blast from an air compressor.

(1) **Aeration Process.**—This removal may be at *ordinary atmospheric pressure*, as by the wind on drying floors, drying pans, drying gantries when in the open, or in sheds, kilns, stoves, and cylinders working without any mechanical draft. In this case the current or movement is caused by the difference in weight between the warm and cold air. The cold air being heavier naturally gravitates downwards, and lifts the more buoyant warm air. Hence the uneven drying capacity in relation to the quantity of heat absorbed. For the air may be displaced before it has obtained its full burden of vapour, as in high temperatures. Or the difference in weight may be insufficient to displace the saturated air as rapidly as the vaporisation proceeds in the case of low temperatures, especially where there is but a small difference in the temperature in the dryer and that outside.

This may for convenience be called the *atmospheric* or *aeration process*, and being dependent on varying atmospheric conditions is unreliable in the quantity of water evaporated, and the quality of the consequent drying. Further, while in some instances the generation of the heat may be the most economical and efficient, the drying is far from economical or efficient, owing to the waste of heat in removing the vapour. Besides which, as the air is all drawn or rolls inwards because it is heavier, as being colder, it is also naturally tending to retard the vaporisation, which after all is entirely dependent on heat. The colder the air the more it will tend to gravitate towards the material which is being and must be warmed in order to facilitate the vaporisation. This process, however, requires no motive power or machinery with the contingent expense of working and upkeep, besides the original first cost. Working at high temperatures, the percentage of loss under this process is less than would appear at first sight.

(2) **Exhaust Process.**—The air may be drawn away quicker than gravity would perform the removal. This necessitates some mechanical assistance, usually a propeller or fan, and according to the degree of this assistance, tends to create a rarefied condition of the atmosphere which intensifies the difference of weight. The surrounding atmosphere endeavours to close in from all directions to equalise the conditions, and thus supplies the fresh air to continue the process. This is the *exhaust process*, and has the advantage over the atmospheric process in that by lessening the pressure of the air, vaporisation proceeds quicker at the same temperature, besides the increased speed and capacity arising from the more rapid removal of the vapour itself. The exhaust process partially removes the uncertainty of the atmospheric conditions, but obviously only to the limited extent of giving a positive current. As it takes that current from the outside, even if it be warmed after entry, it is still subservient to the conditions obtaining in the source of supply, which vary greatly.

The exhaust process gives a positive amount of current, but owing to the fluidity of air it is very difficult to ensure that the exhausted air has been in contact with the source of heat to obtain vaporising capacity, or with the material which has to be dried, to perform its functions as heat conveyor and vapour remover. The fan, of whatever kind, will draw its supply from the nearest and coldest source, whether it is a leak in the dryer or not. Hence the more powerful the exhaust, the more need to carefully watch the design and manufacture of the dryer. In all cases the exhaust process is tending to withdraw the heat bearing medium from the material which has to be heated, and it may do this to an extent as to retard the production of vapour, and thus to counterbalance the advantage of the increased removal of the vapour when formed.

(3) **Vacuum Process.**—If the materials to be dried are enclosed in an oven or receptacle which is air-tight, then the process of withdrawing or exhausting the air may be continued so as to produce a practical vacuum, and the vapour withdrawn without the intervention of any air or other medium. This is called the *vacuum process*, and given suitable materials, the proper application of this process offers great economies of fuel and time. By

reducing the pressure, the heat units are assisted in transmission to the wet material, hence the vaporisation goes on much quicker. With the reduced pressure the boiling point is lowered, and as the boiling point is approached, so the vaporisation tends to proceed throughout the mass of the substance, instead of merely on the free surface. Further, the vapour being withdrawn promptly, and no source of leakage for the heat being possible, the whole process is working under ideal conditions for heating and vaporising the moisture, and, if the vapour were not so attenuated, for its rapid removal also.

Like all powerful or quick working machines or processes, the vacuum process needs considerable experience in applying to various materials, and promptitude combined with skill in usage, hence this process should only be used by experienced hands according to the instructions of experts. The removal of the air pressure allows the water or moisture in the material to come to boiling point at comparatively low temperatures, which obviously accelerates the vaporisation, but the material may be one which boiling, even at a low temperature, would injuriously affect by increasing its porosity or volatilising some desirable constituent. Then, again, while the water is in the material, all the heat available can be usefully absorbed by it even at the increased rate which the reduced pressure allows. But so soon as the water is vaporised, the heat being supplied and the reserve of heat in the oven or receptacle has only the material to warm, and the temperature to which it will do this depends on the specific heat of that material. So the rise in temperature in the material may be an injurious one if promptitude and skill are lacking on the part of the attendant. The makers of repute design their apparatus to minimise these obvious risks to the utmost possible extent, and have in the continuous machines arranged the automatic feed and delivery of amenable materials in a manner to save to a very large extent the expense of skilled attendance.

(4) **Plenum Process.**—Another mode of removing the vapour is to supply such a superabundance of air as to create a state of more than atmospheric pressure or plenum. This is called the *plenum process*, and is obviously only applicable in an enclosed room or receptacle with regulated egress for the air.

Supplying the heated and therefore expanded air under pressure ensures a complete intimate contact to every accessible portion of the surface of the wet material and the room with its fixtures, thus all are heated thoroughly and as efficiently as possible by the use of air. The pressure prevents any cold currents entering to cause condensation or use up the heat unprofitably. Any leaks are positive losses of heat, but they do not neutralise the action of the remaining air. The material is kept in a uniform warm state. The quality, volume, temperature, and point of admission are strictly under control in each portion of the dryer, and they can be promptly and accurately varied from time to time as may be desirable to accommodate the nature and condition of the wet or dry material. While the water is abundant in the wet material a higher temperature may be maintained and gradually or instantaneously lowered as the material dries without any necessity of removing or modifying the position of the material. This is then an adaptable and positive plan, specially effective in obtaining that intimate contact which ensures equalised heating and therefore vaporisation. The increased pressure need not be much over that of the atmospheric conditions; however, every increase of pressure means retarding the vaporisation, and to this extent the plenum process works at a disadvantage.

(5) **Compression Process.** — This is only used under exceptional circumstances, as it must necessarily be an expensive process compared with the amount of moisture removed. The compression of the air naturally absorbs considerable power and desiccates it to some extent. Usually the air is further desiccated by passing over or through broken calcium chloride before it is injected into the space to be dried. An efficient machine working on this principle is illustrated in Fig. 168 for use in cable desiccating. Compression is also used on a large scale in desiccating the air for use in cupola and furnace practice. It is found that by desiccating and heating the blast great fuel economies are effected, while the output per day of the furnace is also considerably increased.

Comparative Features.—Taking a general and comparative view of these processes it will be found that each has considerable advantages and some disadvantages, also that these are both relative to each other and not absolutely advantageous or disadvantageous from every aspect. Further, that these tend to suit the condition and circumstances of different materials. For instance, the absence of any essential machinery in the aeration process in high temperatures sometimes outweighs all disadvantages. The increased vapour removal and improved draft in the exhaust process often tend to produce the air-dried results which are particularly required in some products. The rapid and thorough heating and vaporisation of the vacuum process are essentially suited for desiccating with economy and the utmost efficiency. The pressure and positive control of the plenum process are conspicuously suitable to obtain the intimate contact and equable action in delicate and intricate materials or fabrics which would be contaminated by a polluted atmosphere. The several characteristics of the material to be dried help to decide the process most suitable for that particular material. It is the wet material and the *finished product* desired which must eventually decide the process to be applied, often quite overruling any economies or disadvantages which may be in the process. Hence the need of wide experience in materials and the various modifications of the several processes in deciding the most adequate plant to meet the specific requirements.

Wind and Chimneys.

Winds.—The winds or the natural air currents caused by the different density of cold and warm air are powerful means of drying, but generally so unreliable in their amount and degree as to be quite out of consideration for ordinary present-day commercial purposes. Where air-dried products are sought, however, the extra price obtained will in some cases allow for the delays and extra ground needed. Of course there is the big consideration that the heat and vapour removing are free of cost in fuel and power, while the appliances are only such as to open out the material for the greatest possible surface exposure. Actual experiments with the winds very clearly demonstrate the great importance of rapid changes in accelerating drying at the same temperature, for water exposed in an open vessel evaporated more than twelve times as fast in a moderate gale to what it did in a calm air.

TABLE XVIII.—WIND VELOCITY AND SCALE.

Beaufort's Scale.	Description.	Velocity in miles per hour.
0	Calm - - -	3
1	Light air - -	8
2	Light breeze -	13
3	Gentle breeze -	18
4	Moderate breeze -	23
5	Fresh breeze -	28
6	Strong breeze -	34
7	Moderate gale -	40
8	Fresh gale - -	48
9	Strong gale -	56
10	Whole gale - -	65
11	Storm - - -	75
12	Hurricane - -	90

—*J. G. Symons.*

Chimneys labour under the same disadvantage as the wind in regard to unreliability in their results, but not to the same extent, while by an increased fuel cost the disadvantage may be overcome as it arises. But for drying it is particularly objectionable to have an appliance which works to the greatest disadvantage in a humid atmosphere just where drying is most called for.

The air currents in chimneys arise from difference of gravity between the air in them and that in the external air, hence, as Table XIX. shows, the greater the excess of heat in the chimney, the greater the quantity of air removed. Further, as the height increases, the column of air in it is lighter than a corresponding column of external air, and so the extra weight produces an extra velocity. The heat is thus absolutely essential to produce the current in the chimney, and serves no other purpose. Measured by the mechanical work done compared with the heat absorbed, chimneys show remarkably low efficiency, as only about six ten-thousandths of the heat expended is represented by work done, even under fairly favourable conditions.

In regard to drying, too, it is also necessary to bear in mind, when considering the chimney as a means of extracting vapour, that the air mixture leaving the dryer is heavier than that entering it. The vapour is lighter than air at the same temperature, and to a certain extent displaces the air, but the air has given up its heat to the material and in vaporising the water. Thus the more efficiently the air has done its work, the colder and, therefore, heavier it is. Hence, in using a chimney as an accessory to drying, it should extract at the bottom of the drying-room. It has, however, to be borne in mind that other conditions remaining similar, the hotter the air leaves the drying-room the more capable it is of carrying vapour, so that the heat is not so entirely lost as is the case in a chimney from a furnace which is not also drying.

TABLE XIX.—VOLUME DISCHARGED BY DIFFERENCE OF TEMPERATURE.

Per minute through a duct, of which the cross-sectional area is 1 sq. ft. (the external temperature of air being 32° Fahr.)

Height of Vent Duct in Feet.	Excess of Temperature of Air in Vent-Duct above that of External Air.								
	5°	10°	15°	20°	25°	30°	50°	100°	150°
10	77	108	133	153	171	188	242	342	419
15	94	133	162	188	210	230	297	419	514
20	108	153	188	217	242	265	342	484	593
25	121	171	210	242	271	297	383	541	663
30	133	188	230	265	297	325	419	593	726
35	143	203	248	286	320	351	453	640	784
40	153	217	265	306	342	375	484	656	838
45	162	230	282	325	363	398	514	476	889
50	171	242	297	342	383	419	541	278	937

Timber Drying without Mechanical Aids.—In fact, in 1897 a very ingenious plan of utilising a chimney for drying timber without any mechanism was patented. The working is on the progressive tunnel or shed system, where the timber on trucks passes into the tunnel at one end wet, and out at the other thoroughly dried. The track for the trucks is on a false floor, beneath which at the delivery end is a coiled pipe heater.

The heated air being lighter rises up through the false floor and thoroughly mingles with the timber, and as it passes to the receiving end becomes partially saturated with vapour, and colder by the amount of heat used to vaporise this moisture and losses by radiation. It has gained relative weight per cubic foot, and rolls down the opening in the floor. Under the floor is the duct to a vertical shaft or chimney, into which the saturated air flows. Although considerably cooler than the air supplied by the heater it is still at a higher temperature than the external air, and, therefore, rises, carrying with it the burden of moisture as vapour.

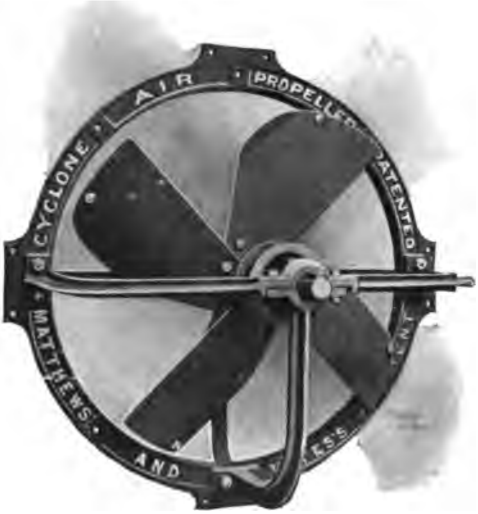


FIG. 55.—AIR PROPELLER. GENERAL VIEW.
(Matthews & Yates, Ltd.)

It is an automatic method of utilising the varying density of the same weight of air as it gains or loses heat, and offers great economies of fuel and labour. For further particulars of this system see Fig. 115.

Fans.

Although there are many kinds of fans there are only two types as being based on different principles of action: (1) the

Disc or Propeller, and (2) the Centrifugal or Peripheral Discharge Fan.

(1) **Propellers.**—The *Disc Wheel* or *Propeller* is constructed on the same principle as the screw propeller used in ships, the blades being so placed as to move the air in lines parallel to its axis, each blade acting as a revolving inclined plane. The different makers naturally adopt different designs, but a typical construction is clearly shown in Fig. 55, a general view, Fig. 56, an elevation, and Fig. 57, a plan. They can be run vertically as shown, horizontally, or at any required angle, by modifying the bearing to allow of suitable lubrication for their high speed. The motive power required is very small, and can readily be applied by belt, as shown, or by direct electric motor. They are applicable for moving volumes of air at comparatively slow velocities, where there is no resistance to be overcome. Their efficiency rapidly decreases as the resistance to the flow increases; it is essential, therefore, if ducts cannot be avoided that they should be of ample area relative to the size of the fan. Hence propellers are much more suited for ventilating purposes

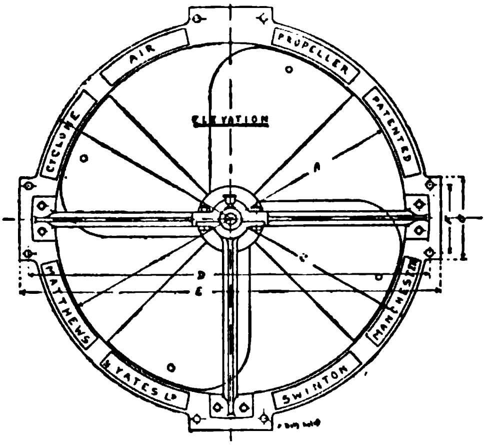


FIG. 56.—AIR PROPELLER. ELEVATION.
(Matthews & Yates, Ltd.)

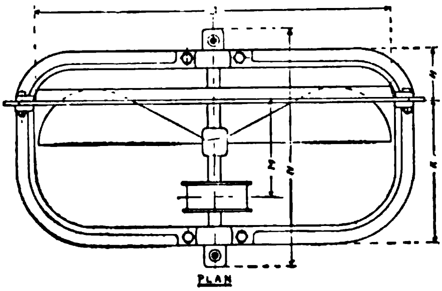


FIG. 57.—AIR PROPELLER. PLAN.
(Matthews & Yates, Ltd.)

than for drying operations, but are sometimes used with the exhaust processes. If situated immediately above the point of evaporation, and discharging directly through a wall into the open they can be used advantageously. They are not capable of producing sufficient difference to meet the requirements of a full exhaust or of a plenum process plant.

(2) **Centrifugal Fans.**—The *Centrifugal Fan* is generally known as a *fan* or a *blower.* As illustrated in Fig. 58, by front and side elevation, it consists of a number of blades extending radially from the axis. As the flat blades revolve, the air is drawn in at the centre, and delivered from the tips of the blades in a tangential direction. The steel casing encloses the sides and periphery, except in the direction the air is required, and so prevents general discharge, and ensures a concentrated blast. When the fan is required for exhausting, there is generally only one inlet for convenience of connecting the duct, while for blowing, an inlet is left on each side to give ample supply. In other respects a *blower* and an *exhauster* are usually alike. The modifications of the various makers are more or less successful attempts at increasing the efficiency by facilitating the ingress and concentrating the output.

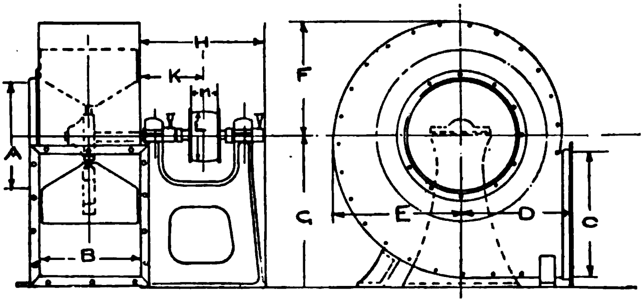


FIG. 58.—CENTRIFUGAL FAN. ELEVATIONS.
(Matthews & Yates, Ltd.)

The *Sturtevant Centrifugal Fan* illustrated in Fig. 59 is of their *Multivane* type for steel plate casing. This type has been specially designed for moving large volumes of air with the least expenditure of power, particularly where the resistance to the passage of the air is relatively small. From the dismantled details it will be seen that the wheel of the fan is provided with a number of comparatively small vanes round its circumference instead of having flat blades radiating from the centre as described under Fig. 58.

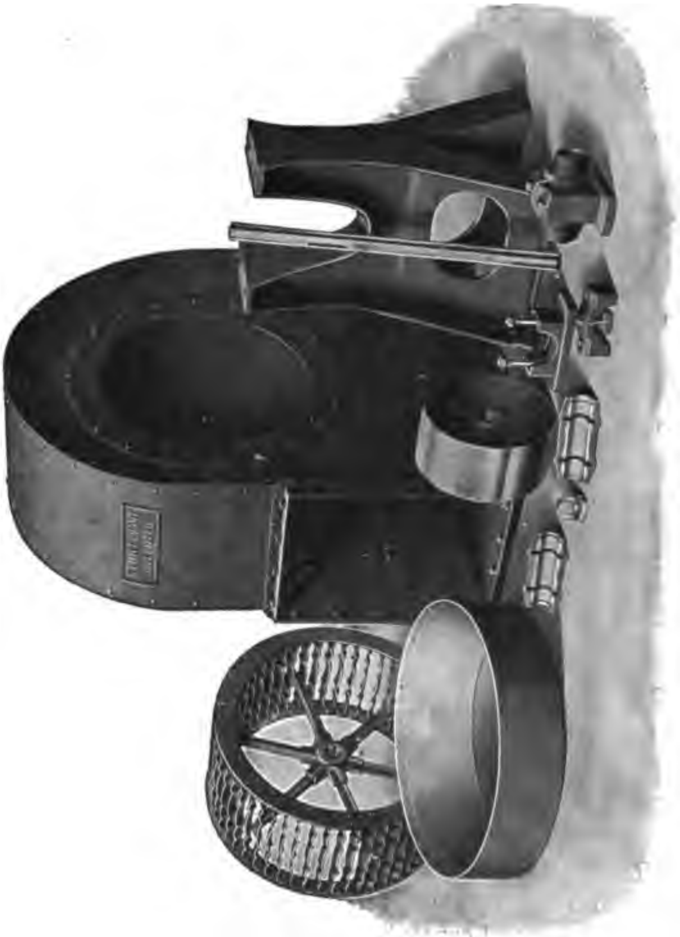


FIG. 59.—STURTEVANT MULTIVANE CENTRIFUGAL FAN. DISMANTLED.
(Sturtevant Engineering Co., Ltd.)

The blades curve forward so that the concave sides face in the direction of rotation. But a more important feature is that the blades are not flat from end to end, but each consists of a series of pockets approximately spoon-shaped, so that the whole of the width of fan handles its due proportion of air. The case and wheel are built of substantial steel plate. The wheel is overhung on the shaft, leaving the inlet unobstructed, so that pipe connections can be readily attached when required. The bearings are long and massive, with ring automatic lubrication.

The form illustrated in Fig. 60, by back and front view, of a fan specially designed for applying to a wall, shows the blades increased greatly in number and shortened in length. The framework carrying the blades is reduced in section, thus allowing the greatest possible space for axial ingress, and reducing the obstruction to the flow of the ingoing air to a minimum.

Action.—The centrifugal fan operates through the air, set in motion by revolving blades, being delivered tangentially at the circumference of the wheel. The removal of the air by this centrifugal force tends to cause a vacuum at the axis and the external air rushes in, to itself be in turn removed. The force of this centrifugal discharge depends on the circumferential speed of the wheel. With ample inlets the degree of vacuum corresponds with the theoretical force, and the velocity of the discharge is substantially equal to the pressure when there is ample free outlet.

Design.—In using the fan as a means to obtain certain pressures the Table XX. forms a guide to the speeds and powers theoretically necessary to employ. For in order to obtain a given pressure in a certain volume it must discharge through a free aperture at a fixed velocity. The volume is regulated by the size of the outlet aperture for the velocity. The velocity of flow is decided by the velocity of the fan tips or the circumferential speed of the fan. Hence to increase the pressure at a given outlet aperture, it is necessary either to increase the diameter of the fan or the speed of revolution, while to increase the volume at the same pressure it is necessary to increase the width of the fan and the outlet aperture.

Thus a fan can be of small diameter, yet by running at high speed produce high pressures and by width move large volumes. In practice it is found advisable and economical to strike a

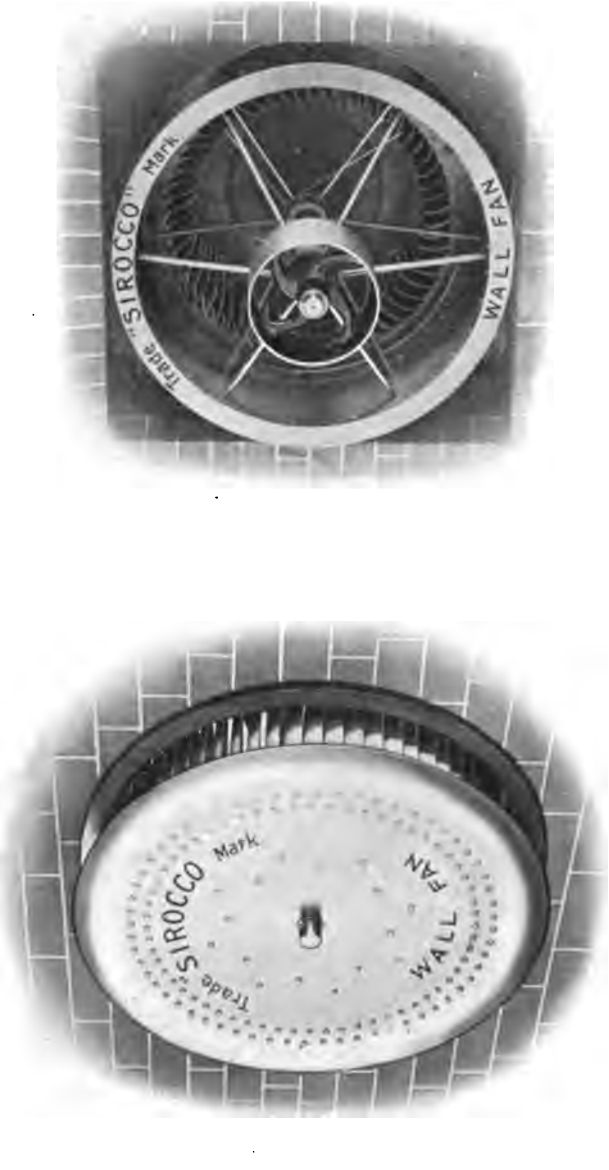


FIG. 60.—SIROCCO WALL FAN. BACK AND FRONT VIEWS.
(Davidson & Co., Ltd.)

TABLE XX.—VELOCITY CREATED, VOLUME DISCHARGED, AND HORSE-POWER REQUIRED

When air under a given pressure in ounces per square inch is allowed to escape into the atmosphere at 50° Fahr.

Pressure, Ounces per Square Inch.	Velocity of Air Escaping into Atmosphere.		Volume Discharged in One Minute through Effective Area of 1 Sq. In in Cubic Feet.	Horse-Power of Air Blast.
	In Feet per Second.	In Feet per Minute.		
⅛	30·47	1,828	12·69	0·0004
¼	43·08	2,585	17·95	0·001
⅜	52·75	3,165	21·98	0·002
½	60·90	3,654	25·37	0·003
⅝	68·07	4,084	28·36	0·005
¾	74·54	4,473	31·06	0·006
⅞	80·50	4,830	33·54	0·008
1	86·03	5,162	35·85	0·010
1¼	96·13	5,768	40·06	0·014
1½	105·25	6,315	43·86	0·020
1¾	113·64	6,818	47·34	0·023
2	121·41	7,284	50·59	0·028
2¼	128·70	7,722	53·63	0·033
2½	135·59	8,136	56·50	0·039
2¾	142·14	8,528	59·22	0·044
3	148·38	8,903	61·83	0·050
3½	160·10	9,606	66·71	0·060
4	170·98	10,259	71·24	0·080
4½	181·16	10,870	75·48	0·09
5	190·76	11,446	79·48	0·11
5½	199·86	11,992	83·24	0·12
6	208·53	12,512	86·89	0·14
7	224·77	13,486	93·66	0·18
8	239·80	14,388	99·92	0·22
9	253·83	15,230	105·76	0·26
10	267·00	16,020	111·25	0·30
11	279·70	16,768	116·45	0·35
12	291·30	17,478	121·38	0·40
13	302·59	18,155	126·06	0·45
14	313·38	18,803	130·57	0·50
15	323·73	19,424	134·89	0·55
16	333·68	20,021	139·03	0·61
17	343·26	20,596	143·03	0·66
18	352·52	21,151	146·88	0·72
19	361·46	21,688	150·61	0·78
20	370·13	22,208	154·22	0·84

In the above table the volume is proportional to the velocity.
The power varies as the cube of the velocity.

mean between the diameters and the speed to obtain any given pressure. As larger volumes are required it would be quite impracticable to proportion the speed to the diameter. On the other hand an excessive diameter for the volume would make an impracticable width. Hence each maker fixes his own proportion as his experience points and often in accordance with the proposed means of motive power, especially so in the case of large installations.

Efficiency.—From the mechanical aspect, as a means of moving air the fan is much more efficient than a chimney. As previously mentioned, a well-designed chimney, working under favourable conditions, produces less than six ten-thousandths of the mechanical effect which its heat energy is capable, although it acts directly. A fan, however, has to take its power indirectly, and at each step of the transmission there are losses to its efficiency.

TABLE XXI.—PRESSURE IN INCHES OF WATER.

And corresponding Pressure in Ounces per square inch, with Velocities of Air due to Pressures.

Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.	Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.
$\frac{1}{32}$	0·01817	696·78	$\frac{5}{8}$	0·36340	3118·38
$\frac{1}{16}$	0·03634	987·66	$\frac{3}{4}$	0·43608	3416·64
$\frac{1}{8}$	0·07268	1393·75	$\frac{7}{8}$	0·50870	3690·62
$\frac{3}{16}$	0·10902	1707·00	1	0·58140	3946·17
$\frac{1}{4}$	0·14536	1971·30	$1\frac{1}{4}$	0·72670	4362·62
$\frac{5}{16}$	0·18170	2204·16	$1\frac{1}{2}$	0·87210	4836·06
$\frac{3}{8}$	0·21804	2414·70	$1\frac{3}{4}$	1·01740	5224·98
$\frac{1}{2}$	0·29072	2788·74	2	1·16280	5587·58

Thus taking 1,000 ft.-lb. at the source of energy and allowing a loss of 90 per cent. for the engine, there are 100 ft.-lb. imparted to the fan whose loss may be taken as 50 per cent., leaving 50 ft.-lb. for work. Assuming this to have a loss of 20 per cent. through friction, it still leaves 40 ft.-lb. for useful work, that is, 40 out of 1,000 or an efficiency of $\frac{4}{100}$ as compared with the chimney $\frac{8}{10000}$, that is, the fan is over sixty times as efficient as the chimney.

Since each maker decides his own proportion between diameter and width, each of necessity should give a list of the various speeds necessary to obtain the volume at certain pressures. As the design will materially affect the theoretical outputs, no useful table can be given for general use. In all cases the following general allowances should be made from the actual outputs of the special fan as tested with a free outlet and unobstructed delivery.

Allowances for Position.—The actual losses will vary according to the position of the fan in the system, but the percentages given are ones to cover ordinary applications.

When applying heat:—

Deduct 30 per cent. from the volume delivered.
„ 10 per cent. from the horse-power required.
Velocity of air through discharge outlet, 55 per cent. greater.
Pressure per square inch, 140 per cent. greater.

When forcing draft:—

Deduct 60 per cent. from volume delivered.
„ 25 per cent. from horse-power required.
Velocity of air through discharge outlet, 90 per cent. greater.
Pressure per square inch, 250 per cent. greater.

In connection with drying it is especially necessary to have ample volume of air, and so it is economical to instal a large fan rather than a small one running at high speed, since the large fan, though higher in first cost, is continuously less expensive to run. Where forced draft is also used for generating the steam in connection with drying, then pressure is of more consideration, and while retaining the large fan a narrower width is most suitable.

Normair Alternating Twin Fan.—Where it is required to alternately apply air under pressure in order to ensure intimate contact, and to abstract the vitiated air with a certain degree of exhaust to accelerate vaporisation, a special duplex fan has been designed. This apparatus, shown in Fig. 61, is self-contained by one compact base-plate, and consists of two centrifugal fans driven by one straight belt. This belt is held and guided by a belt fork controlled by a lever which works in a roller cam. This roller cam is cut to ensure the belt fork lever remaining in one position a fixed number of revolutions, it then moves it to a second position for a fixed number of revolu-

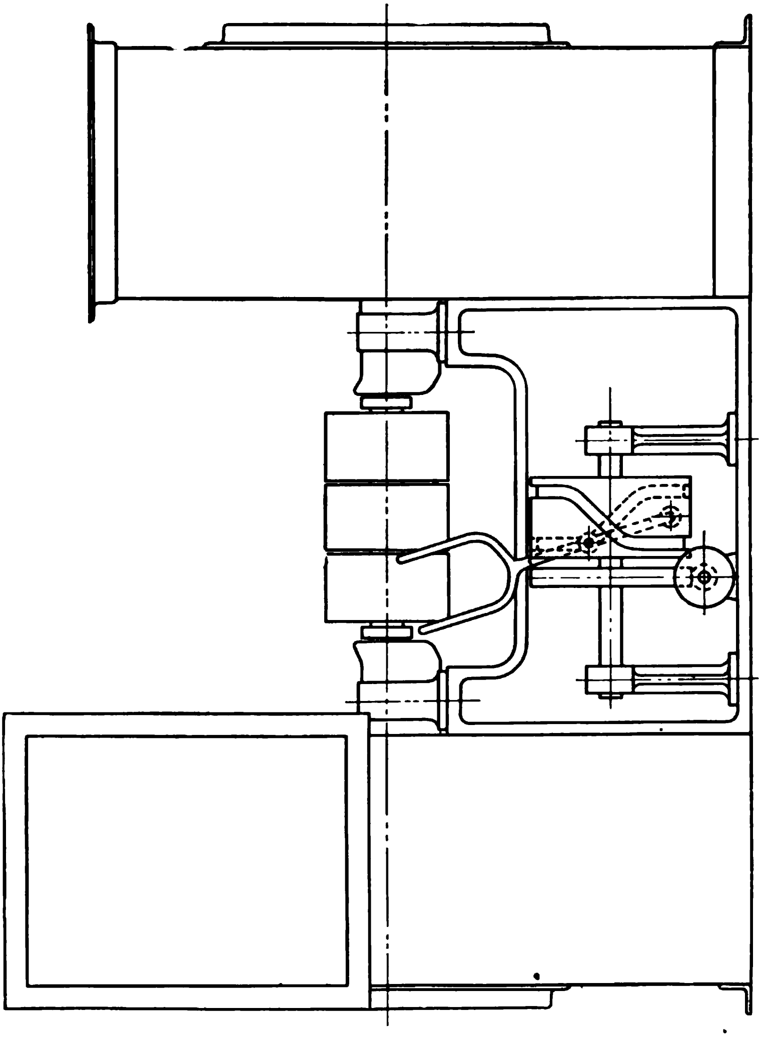


FIG. 61.—NORMAIR ALTERNATING TWIN FAN.
(Pulsometer Engineering Co., Ltd.)

tions, and afterwards into a third position for a fixed number of revolutions. Having completed its transit the belt fork lever returns to the second position, then to the first, again to the second and third, and so on. When the belt fork is in the first position it drives the exhaust fan, in the second position it is on a loose pulley, in the third position it drives the pressure fan. Thus automatically the two fans are driven intermittently with a fixed period of rest between each run. Of course the cam roller needs to be driven by a small belt from the same shaft.

Root's Blower.—A type of fan which gives a steady blast suitable for plenum process of drying is illustrated in Fig. 62; it is also well suited for the pneumatic handling of long fibred and other material mentioned in Chapter VII. under "Handling Material." It consists essentially of two impellers usually of cast iron planed to the curves shown in the section, enclosed in a closely fitting box, having top inlet and outlet through base. The drive is preferably with single belt and double spur gearing. The spur gearing should be enclosed and well oiled. With a well-proportioned and carefully manufactured machine this form gives a very even pressure, with a large output at slow speed and small power. It is particularly positive and reliable in action. Fig. 63 gives a general view of an exhauster built on the same principle.

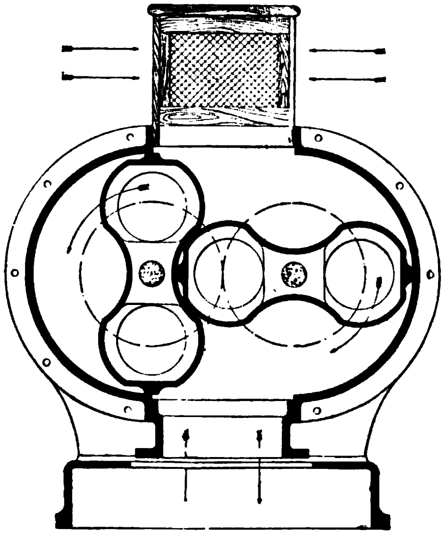


FIG. 62.—ROOT'S BLOWER. SECTION.
(Thwaites Bros., Ltd.)

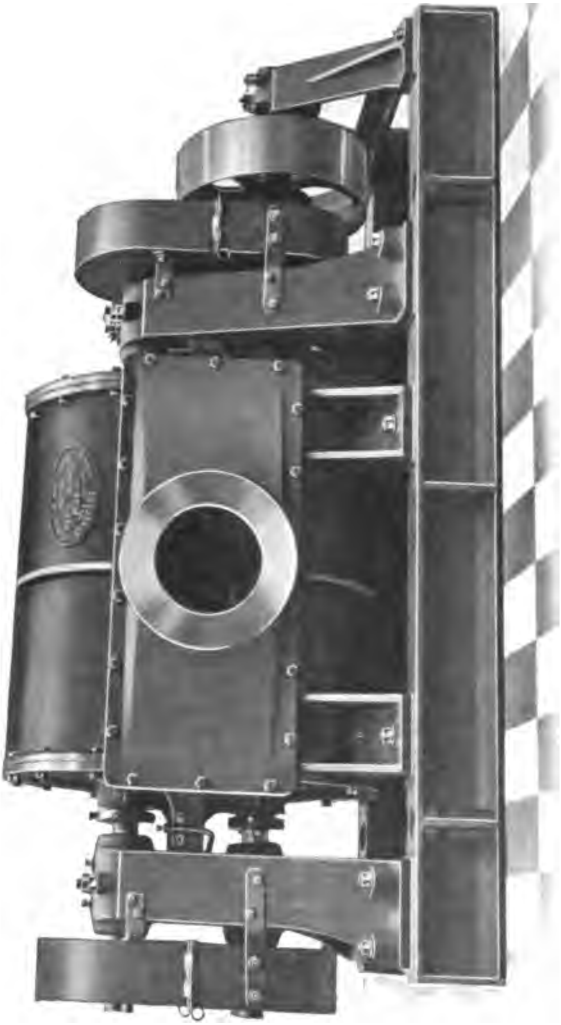


FIG. 63.—ROOT'S EXHAUSTER. GENERAL VIEW.
(Thwaites Bros., Ltd.)

Air Pumps.

Air or *Vacuum Pumps* are used for drying in connection with the vacuum process, being an essential feature of such plant. Having to deal with vapour produced under low pressures and low temperatures, the design and manufacture of the pump require to be of high class. Each maker of this type of dryer has his own special design generally similar to those used on condensing engines. Usually steam driven with mechanically acting valves to ensure positive control, they should be specially regulated to suit the particular size of the machine and the material, as any failure in their action may mean waste of the material.

In Fig. 64 is illustrated the *Scott Vacuum Pump* specially designed for vacuum drying plants and to occupy a small space. The base-plate and framing are one casting of suitable proportions to obtain rigidity, the cross-head, which is of the trunk-guide type, being formed in the framing. The air and steam cylinders are superimposed, their pistons being attached to the same rod. Both cylinders have slide valves actuated by eccentric and rods from the main crankshaft.

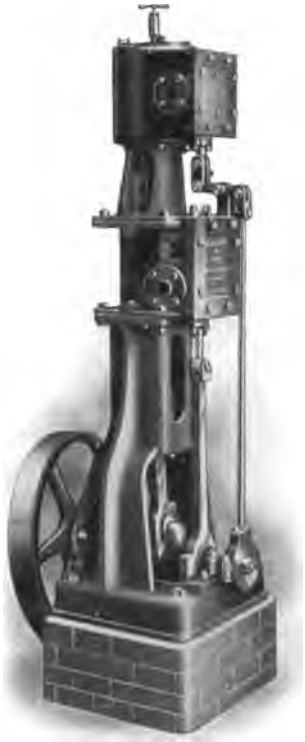


FIG. 64.—VERTICAL VACUUM PUMP.
(Geo. Scott & Son, Ltd.)

Drying Capacities.

Determining Factors.—From the preceding statements and tables there can be reckoned the capacity of a given quantity of heat units to vaporise water, but these capacities are only when the heat is applied under such favourable circumstances as in practice are not possible. The actual weight of water which a given number of thermal units will evaporate depends on many factors, among which may be mentioned (1) the nature of the material, (2) the amount of free surface, (3) the amount of exposure, (4) the method of application, (5) the rapidity of removal of the vapour, (6) the dissipation of heat by surroundings, (7) the temperature, &c. As vaporising is the primary step in drying, the same factors will operate, and the removal of the vapour becomes of the more vital import since the drying only commences on the removal of the vapour. Hence while heat is the essential preliminary agent in all evaporative drying, the abstraction of the vapour is the deciding factor in the efficiency of the drying. In all the preceding tables, formulæ, and calculations, it must be borne in mind that capacities are referred to, not results or efficiencies. The results obtainable cannot reach these capacities owing to the losses mentioned previously, and the results obtained will vary even more according to the design and manufacture of the particular plant, also to a large extent on the skill with which the plant is manipulated. In describing the installations and appliances some data for well made and carefully worked plants are given which will show the actual amount of the available capacity which obtains in good practice.

Boiler Results.—To heat water at 32° Fahr. to 212° Fahr. requires $212-32$ B.Th.U. $=180$ B.Th.U., which show on a thermometer. To convert this water at 212° Fahr. to steam or vapour at 212° Fahr. requires 966 B.Th.U., which do not show on a thermometer.

Therefore the total heat present in steam or vapour at 212° Fahr. is $180+966=1{,}146$ B.Th.U. (Table XXII.). As a first-class coal contains more than 14,000 B.Th.U. to the pound (Table V.), it would appear that 1 lb. of coal should heat $\frac{14{,}000}{1{,}146}$ lb. of water to steam at 212°, that is 12·2 lb. of steam.

But the best boilers in existence would not produce more than 10 lb. of steam at 212° Fahr. from 1 lb. of best coal, even when the feed water was much higher than 32° Fahr. (In actual practice no water would be used at 32°.) Thus in the conversion of the fuel to steam there is a minimum unavoidable loss of over 25 per cent. But this loss is one of conversion, and should not be reckoned against the drying efficiency when comparing drying installations which use steam as their source of heat. Really there is now 1 lb. of steam which contains 1,146 B.Th.U., although it has taken $\frac{14,000}{10} = 1,400$ B.Th.U. or more to produce it, and the only just test for comparison of dryers using steam is the amount dried per pound of steam used.

Steam Conversion.—Taking this 1 lb. of steam at 212° Fahr. as containing 1,146 B.Th.U. to warm some air. The specific heat of dry air is. 0·238, therefore this 1 lb. of steam should heat

$\frac{1,146}{\cdot 238}$ lb. $= 4,815$ lb. of air 1° Fahr.

$= 4,815 \times 13{\cdot}12$ cub. ft. of air 1° Fahr. (taking air at 62° Fahr. as 13·12 cub. ft. to the pound)

$= 63,173$ cub. ft. of air.

In actual practice, owing to condensation and other losses, mentioned p. 102, it is found that this 63,173 cub. ft. becomes reduced to about 40,000 cub. ft. as a maximum under the most favourable conditions, and with the best type of heater and connections. In other words, it takes the 1,146 B.Th.U. contained in a pound of steam at 212° to warm 40,000 cub. ft. of air 1°, or 1,000 cub. ft. 40°, say from 62° to 102° Fahr. This is a loss incidental to the transmission of the heat from the steam to the air, and is really a loss of drying efficiency as compared with dryers which do not use steam.

This 1,000 cub. ft. of dry air at 62° Fahr. on being raised to 102° Fahr. increases its vapour capacity from ·881 lb. to 2·997 lb. Therefore it should deal with $2{\cdot}997 - {\cdot}881$ lb $= 2{\cdot}116$ lb. of vapour.

If the air remained at the 102° which it enters the drying

TABLE XXII.—PROPERTIES OF SATURATED MIXTURES OF AIR AND AQUEOUS VAPOURS UNDER A CONSTANT PRESSURE OF 14·7 LB. PER SQUARE INCH.

Dewpoint, or Final Temperature of the Saturated Mixture.	Total Pressure per Square Inch.		Weight of 100 cub. ft.			Quantity of Heat in 100 cub. ft., reckoned from 32° Fahr. (Water at 32° Fahr. for Vapour).			Quantity of Heat in 1 lb. of Vapour, reckoned from Water at 32° Fahr.	Quantity of Dry Air required for 1 lb. of Vapour in Saturated Mixture.		Required Initial Temperature of the Dry Air to Evaporate 1 lb. of Moisture in Saturated Mixture.
	Vapour.	Air.	Vapour.	Air.	Saturated Mixture.	Vapour.	Air.	Saturated Mixture.		Weight.	Volume at 62° F.	
Deg. Fahr.	Lb.	Lb.	Lb.	Lb.	Lb.	B.Th.U.	B.Th.U.	B.Th.U.	B.Th.U.	Lb.	Cub. Ft.	Deg. Fahr.
32	·089	14·611	·031	8·023	8·042	33·8	0·0	33·8	1091·2	258·8	3,401	49·7
35	·100	14·578	·034	7·970	8·004	37·1	5·7	42·8	1092·1	234·4	3,080	54·6
40	·122	14·578	·041	7·879	7·920	44·8	15·0	59·8	1093·6	192·2	2,526	63·8
45	·147	14·553	·049	7·785	7·834	53·6	24·0	77·7	1095·1	158·9	2,088	74·0
50	·178	14·522	·059	7·693	7·752	64·7	32·9	97·6	1096·6	130·4	1,714	85·4
55	.214	14·486	·070	7·598	7·668	76·8	41·5	118·3	1098·2	108·5	1,426	97·6
60	·254	14·446	·082	7·507	7·589	90·1	50·0	140·1	1099·7	91·6	1,203	110·5
65	·304	14·396	·097	7·410	7·507	106·8	58·1	164·9	1101·2	76·4	1,004	125·6
70	·360	14·340	·114	7·311	7·425	125·6	64·1	189·7	1102·8	66·0	868	140·0
75	·427	14·276	·134	7·208	7·342	147·9	73·7	221·6	1104·3	55·0	723	160·0
80	·503	14·197	·156	7·106	7·262	172·5	81·1	253·6	1105·8	45·6	599	182·0
85	·592	14·108	·182	6·996	7·178	201·6	88·1	289·7	1107·3	38·4	505	206·0
90	·693	14·007	·212	6·896	7·108	235·1	95·1	330·2	1108·9	32·5	427	233·0
95	·809	13·891	·245	6·764	7·009	272·1	101·3	373·4	1110·4	27·6	363	264·0
100	·942	13·758	·283	6·641	6·924	314·7	107·3	422·0	1111·9	23·5	308	299·0
105	1·095	13·605	·325	6·505	6·830	361·8	112·9	474·7	1113·4	20·0	263	344·0
110	1·267	13·433	·373	6·368	6·741	415·8	118·1	533·9	1115·0	17·1	224	385·0
115	1·462	13·238	·426	6·224	6·650	476·4	122·7	599·1	1116·5	14·6	192	436·0

TABLE XXII.—*Continued.*

Dewpoint, or Final Temperature of the Saturated Mixture.	Total Pressure per Square Inch.		Weight of 100 cub. ft.			Quantity of Heat in 100 cub. ft., reckoned from 32° Fahr. (Water at 32° Fahr. for Vapour).			Quantity of Heat in 1 lb. of Vapour, reckoned from Water at 32° Fahr.	Quantity of Dry Air required for 1 lb. of Vapour in Saturated Mixture.		Required Initial Temperature of the Dry Air to Evaporate 1 lb. of Moisture in Saturated Mixture.
	Vapour.	Air.	Vapour.	Air.	Saturated Mixture.	Vapour.	Air.	Saturated Mixture.		Weight.	Volume at 62° F.	
Deg. Fahr.	Lb.	Lb.	Lb.	Lb.	Lb.	B.Th.U.	B.Th.U.	B.Th.U.	B.Th.U.	Lb.	Cub. Ft.	Deg. Fahr.
120	1·685	13·015	·488	6·063	6·551	545·6	126·8	672·4	1118·0	12·4	163	499
125	1·932	12·768	·554	5·900	6·454	620·1	130·4	750·5	1119·5	10·7	140	567
130	2·215	12·485	·630	5·717	6·347	706·2	133·2	839·4	1121·1	9·1	118	667
135	2·542	12·158	·714	5·524	6·238	801·5	135·2	936·7	1122·6	7·74	102	745
140	2·879	11·821	·806	5·315	6·131	906·0	136·7	1042·7	1124·1	6·61	86·8	856
145	3·273	11·427	·909	5·106	6·015	1023·4	137·2	1160·6	1125·6	5·62	73·8	986
150	3·708	10·992	1·022	4·869	5·891	1151·8	136·6	1288·4	1127·2	4·77	62·6	1,145
155	4·193	10·507	1·145	4·619	5·764	1292·3	135·1	1427·4	1128·7	4·03	53·0	1,332
160	4·731	9·969	1·333	4·346	5·679	1506·5	132·2	1638·7	1130·2	3·26	42·8	1,618
165	5·327	9·373	1·432	4·055	5·487	1620·6	128·2	1748·8	1131·7	2·83	37·1	1,847
170	5·985	8·715	1·602	3·739	5·341	1815·0	122·6	1937·6	1133·3	2·33	30·7	2,212
175	6·708	7·992	1·774	3·402	5·176	2013·1	115·6	2128·7	1134·8	1·92	25·2	2,665
180	7·511	7·189	1·970	3·036	5·006	2239·0	106·8	2345·8	1136·3	1·54	20·3	3,280
185	8·375	6·325	2·181	2·651	4·832	2481·7	96·4	2578·1	1137·8	1·22	16·0	4,124
190	9·335	5·365	2·411	2·231	4·642	2747·0	83·8	2830·8	1139·4	0·93	12·2	5,368
195	10·385	4·315	2·662	1·781	4·443	3037·0	69·0	3106·0	1140·9	0·67	8·8	7,370
200	11·526	3·174	2·933	1·300	4·233	3351·6	51·9	3402·5	1142·4	0·44	5·8	12,840
205	12·770	1·930	3·225	0·785	4·010	3689·5	32·3	3721·8	1143·9	0·24	3·2	19,985
210	14·126	0·574	3·543	0·232	3·775	4058·2	9·8	4068·0	1145·5	0·065	6·86	73,940
212	14·700	0·000	3·683	0·000	3·683	4221·1	0·0	4221·1	1146·1	0·000	0·00	...

—*D. K. Clark.*

chamber this would be so as it could *carry* the vapour. But in drying, the air has to give up its heat *to vaporise the moisture* before it can absorb and carry it. The amount of heat which it must give up to vaporise the water is quite independent of the type of dryer or the method of drying. It is the amount which the vapour will contain as sensible or latent heat, and is given in Table XXII. for temperatures from 32° to 212°. The amount may be fitly called the *productive* portion of the heat, as so far as drying is connected it is the only part which directly produces any result. Hence it might appear that the larger the proportion used in this *productive* function the greater the efficiency and capacity of the machine. This, however, has its limitations, for as the temperature falls the vapour capacity of the space becomes less whether air be present or not, in fact the moisture cannot evaporate above a certain quantity at a given temperature; so that assuming this 1,000 cub. ft. used up *productively* in vaporising half the heat, it obtained and took up $\frac{2{\cdot}116}{2}$ lb. = 1·058 lb. of vapour, thereby falling to 82° Fahr. What occurs? A portion of the heat is dissipated in warming the material, in radiation and conduction from the dryer, and appliances for handling the material, say this is 10°, which is much lower than ordinary, then the temperature is 72°.

Referring to Table XXII. it will be seen that 1,000 cub. ft. of air at 72° can only carry 1·221 lb. of vapour, or only 1·221 − ·881 lb. = ·340 lb., therefore it cannot carry off the 1·058 lb. supposed to have been vaporised even when fully saturated, showing that there is not available the 20° for productive drying. In other words, more than 50 per cent. of the heat brought into the drying chamber is used for other purposes than supplying the heat shown as present in the vapour by Table XXII. Further, for simplicity it has been taken that the 1,000 ft. remained constant, but, of course, the volume would vary at each of the temperatures, and with the variance the carrying capacity also, as is well illustrated in Table VII.

From this it will be seen that the capacity of the dryer is fixed at both ends by the temperatures. For the temperature at the entrance is fixed by the nature of the material, and the temperature at the outlet is fixed by the carrying capacity, since the higher the temperature the more the air can carry; so that for capacity the higher temperatures at entrance and exit have the advantage in increased efficiency, and these temperatures must be decided by experience of the material and working conditions in every case. Then from these Table XXII. gives the quantities of heat which must be obtained for drying, and the factor for incidental losses must again be from experience of the actual type and make of machine. The type of machine has much greater weight than might be supposed even in direct fired kinds, and materials which are not thermally sensitive. For instance in actual tests with fine sand such as is used on railway and tramway tracks, it has been found that a dryer with furnace under a plate-iron floor evaporated only 1 lb. of water to 1 lb. of coal, whereas a rotary cylinder dryer dealt with the same sand and evaporated 8⅓ lb. of water to 1 lb. of coal including the coal consumed for drying the cylinder. From the results stated in the other portion of this work it will be seen that 3 lb. of water evaporated by 1 lb. of coal is excellent work when using steam-heated dryers. Finally it must be borne in mind that the type of machine is nearly always determined by the nature and condition of the wet material in full relation to the nature of the *dried product* which it is desired to obtain. To make any calculations until these are determined is futile and waste of time.

CHAPTER VII

HANDLING THE MATERIAL

General Considerations—Batch Drying—Peat-Turf Gantries—Mechanical Stirrers—Boby Grain Stirrer—Semi-Automatic Feeding—Continuous Feeding and Discharge—Intermittent Progressive Working—Timber Trucks—Erith's Piling Trucks—Steel Rack Brick Cars—Lennox Patent Lifting Bogie Trucks—Conveyors—Bands—Paddle Conveyors—Runways—Manual Labour—Dry-Horses—Frame Conveyor—Safeguards—Scott Valve for Vacuum Apparatus—Dip-Feed—Panelled Rack on Double Track—Superimposed Band Conveyors—Stretching—"Feel"—Handling Hanks—Idiosyncrasies of Materials - - - - - 136-156

General Considerations.—With regard to drying operations the handling of the material has to be viewed from several aspects. There is first the *nature and condition* of the material and its facilities or disabilities with regard to handling. In many cases this is the deciding factor, as the material may require the utmost care as in textile fabrics, or may allow of any reasonable amount of rough usage as stone, sand, or may be improved by thorough agitation and mixing of its component particles.

Even those materials which appear to be incapable of damage may be depreciated by unsuitable handling; for instance, the sharpness may be taken off the sample of stone, which for some purposes is a great disadvantage, *e.g.*, in asphalt. Sand may be "floured" instead of gritty. The method of handling must be suitable for the material.

Then the *cost* aspect raises the question of labour entailed in charging, discharging, or during the process of drying. If these can be automatically arranged without power, as in some louvre stoves, and the material will allow of such, then the economy of labour may mean economy in drying costs. Where the feed and delivery can be mechanically arranged whether the material be handled during the process or not, it may be economical to use the necessary power, while in some instances the handling may be so used in combination with the feed and delivery as to also increase the efficiency of the process, *e.g.*, some cylinders, pans, and stoves.

The *labour* aspect besides cost brings to view the nature of the vapours which are driven off, as these may be obnoxious as in fish, fæces, &c., or injurious as in acids, or even deadly as in white lead and other chemicals. Here mechanical handling is essential, and must be of a nature to control the dangerous and objectionable effluvia.

The amount of *surface exposure* of the material to facilitate intimate contact with the heat medium is also largely connected to the handling either preliminary to or during the process.

The facility for *removing the vapour* by so arranging or modifying the position of the material as to assist rather than block the air currents, is another aspect of handling which often entails skilled labour.

In regard to *fuel economy* the handling is prominent, as continuous drying saves the losses from cooling and reheating in the alternating plans.

In drying-rooms and kilns besides this heat loss there is the strenuous *nature of the work* to be considered, even where the vapours may not be particularly objectionable, as a hot humid atmosphere is always disadvantageous for work.

There are also the cases to be considered where the drying is of such a degree as to suggest a *gradual process* in two or more steps. Here the extra handling and other costs must be balanced by the added value in the finished product. For instance, pigments may be partially dried by precipitation then filter pressed and afterwards dried by evaporation. Peat too has been frozen into a solid brick in order to be broken up, then compressed in order to facilitate drying previous to disintegration. Laundries usually hydro their goods before drying them (see Table II.).

Where goods or materials need water extracted between two other processes of manufacture, the handling often becomes a very interesting process. In such cases of paper manufacture, wool washing and combing, and the electro-deposition of metallic ribbons, the handling is so carefully arranged as to prevent any *interruption to the processes* and forms a continuous automatic combination of operations.

Batch Drying.—The practice of drying a batch or fixed charge at once and then removing it to replace by another batch is often adopted.

In filter frames and vacuum filters a convenient quantity of the wet material is placed on the filter cloth, and then allowed the usual time required by the particular material. Removal is followed by replacement of a corresponding batch. Here labour is considerably out of proportion to the amount of material dealt with. The old type vacuum filter economises the time and increases the efficiency of the drying, but usually small quantities are dealt with at high labour costs. The material is stationary during the process.

In the newer types of continuous vacuum filters, such as Fig. 9 or Figs. 11 and 12, the handling is automatic and the filtration continuous, hence larger outputs and greatly reduced labour costs. The product, too, has a wash and double drying operation in the one circuit.

The filter presses have their wet material fed into the several chambers, and then the pressure brought upon the batch till the operation is complete. The machine is then discharged and reloaded. By the use of the pumps or montejus the feeding is practically labourless, and in the best designed machines the removal of the cake is almost automatic. Thus time and labour are economised. The material is stationary, and only slightly compressed by the pressure.

Hydro-extractors always work by batch, and necessarily stop the machine during loading and unloading; but the time and labour required are but small. The goods or materials rapidly revolve but relatively are at rest.

Centrifugal dryers work by batch, but in many instances can be charged and discharged without any stoppage or any labour except the opening and closing of the necessary feed valves. The centrifugal for preliminary drying of molasses shown in Fig. 24 is so constructed as to obviate the use of valves, and needs no handling to discharge. The materials are rapidly revolved in harmony with the machine, and relatively still.

Gantries are essentially fixtures for carrying the material, which may be treated by fixed charge or continuously as other circumstances dictate. When in the open, the gantries are generally loaded and unloaded continuously. The materials are stationary during the process, and are generally contained in some vessel or receptacle to facilitate handling, but in most cases the labour is considerable.

Peat Turf Gantries.—In Fig. 65 is shown a combined gantry and tramway especially designed to deal with peat.

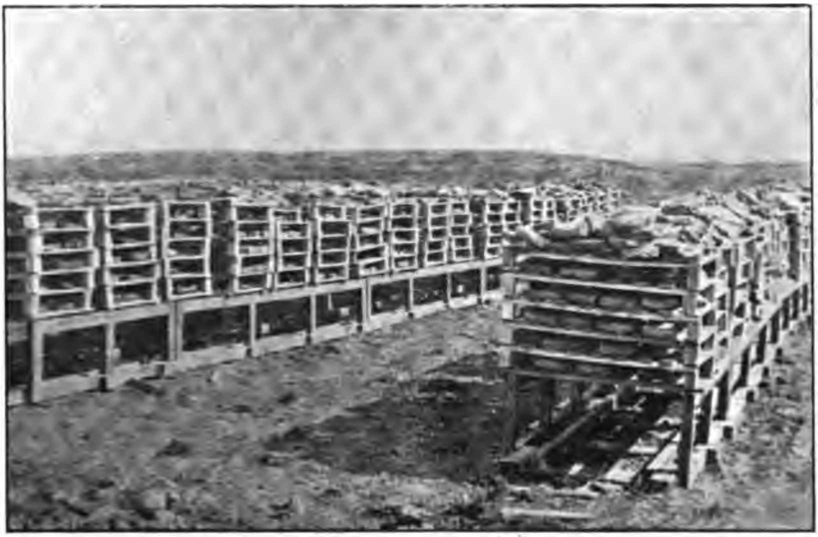


FIG. 65.—PEAT DRYING GANTRIES.
(A. B. Lennox.)

The peat is placed on the pallets, which fit the special lifting and lowering trucks built for this type of tramway. When the truck is loaded it is passed over the tramway to the empty part of the gantry, and discharges its load by one operation, and then is free to be moved away. When the process of drying is complete, the truck can be led under the pallets, and at one operation receives its full load, ready to remove them. The handling and consequent labour is thus greatly reduced. The peat and pallets remain stationary on the gantry during the process.

Mechanical Stirrers.—On drying floors, in most instances, the fixed-charge plan is followed, especially when the charge is deposited on the floor in a very soaked condition, *e.g.*, cement slurry, and in such instances an effort is made to obtain an equal distribution of the heat over the surface of the floor. The creamy semi-liquid material is generally pumped on to the floor or allowed to flow down a duct and find its own level.

Where the material is more granular, or been allowed to settle more, as in china clay or barytes, the material is delivered by truck or barrow, and spread by hand labour in varying thicknesses of layers. The fire end of the floor generally dries quicker than the remainder, and so requires more frequent change, thus becoming partially continuous. In some cases, by careful handling of these less wet materials, it can be arranged that the same truck or barrow returns loaded each journey. The labour is here a big item, and the labour is continually over and among the vapour and heat. The material is usually stationary during the process, but in some instances, *e.g.*, phosphates, it is found economically necessary to have the material turned over one or more times. This turning is generally performed by spade labour, but mechanical hoes are also used, especially in the case of acids, and where drying is preliminary to roasting or calcining. Where the mechanical hoe or rake is used it is sometimes arranged to gradually carry forward the material to the delivery end of the floor, thus making it a continuous and automatic process. Generally, however, such cases have the floor so enclosed as to become a tunnel or oven.

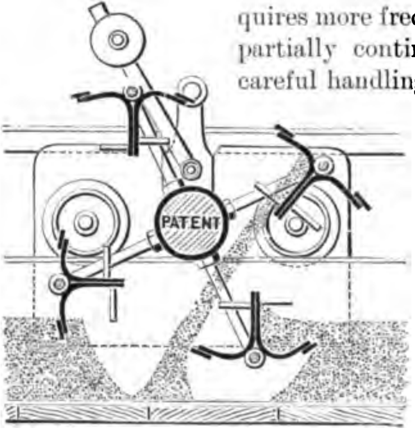


FIG. 66.—AUTOMATIC GRAIN STIRRER (PATENT). ELEVATION. (Robert Boby, Ltd.)

Figs. 66 and 67 show an ingenious hoe or stirrer especially designed to turn malt or grain automatically and evenly throughout the floor, also to automatically reverse itself at each end of the floor. The revolving double-cupped stirrers are self-balancing on four radial arms upon the rotating shaft. The shaft and gear are carried in a carriage frame running on a light track. This enables the malting room to be closed throughout the process, and entirely dispenses with manual labour in so far as the stirring is concerned. The turners are also used for barley sweating kilns and oat drying kilns. They use but little power, ½ to 2 H.P. according to the size of the kiln.

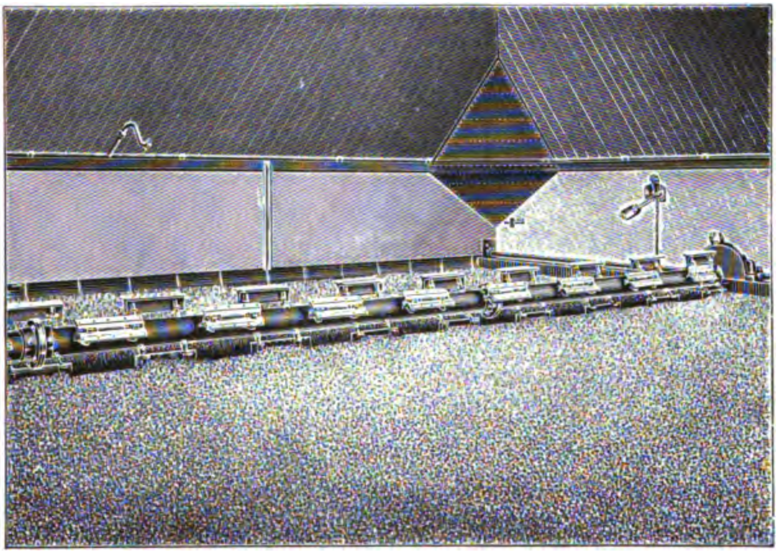


FIG. 67.—AUTOMATIC GRAIN STIRRER (PATENT). *IN SITU.*
(Robert Boby, Ltd.)

Semi-Automatic Feeding.—Drying pans generally deal with soaked materials containing very large percentages of water, and so are almost entirely batch working. Being semi-liquid, the feed is commonly by pump or duct, but the discharge generally entails considerable labour and soon wears out the pan. In some cases, however, as in the one shown in Fig. 82, the pan is automatic in its delivery by means of an outlet valve in the bottom, while some pans are carried on swivels, which allow of the pan being inverted to empty. But the typical pan, *e.g.*, the brine pans, are laborious and slow in their removal operations. In order to obtain any reasonable efficiency and regularity in the drying, the material in pans should be turned over or agitated during the process.

Dry Sheds as sheds offer equal facility to batch or continuous drying, which suits the case, depends on the other accessories used in the drying. But usually a shed receives and retains its charge till the material is dried, as the additional water from fresh, wet materials would tend to delay the other drying.

Kilns generally receive their charge together with the required fuel, and when the fuel is consumed the whole is allowed to cool ready for discharge, *e.g.*, phosphate kilns. In some, however, the fuel is fed and regulated in a furnace under or in the kiln, and this allows for more control over the air supply and the fuel consumption, *e.g.*, fuller's earth, hop, malt, &c. The material is generally stationary either on the floor or on shelves, but in malt, barley, and other grain kilns the material is turned either by manual labour or by mechanical turners, as shown in Fig. 66. In these cases, however, the kiln becomes more of the nature of a drying oven than a kiln, the furnace being quite detached from the space which contains the material.

Drying stoves are generally worked with fixed charges, either with the material on shelves or trays to facilitate removal to and from the machine. In some cases the material is continuously on the move, being fed at the top, and gradually falling down over louvres arranged in various ways to give frequent contact of the material with the hot gases. Then the material is sometimes agitated by stirrers on a rotating shaft, while the hot gases pass through, as well as under, the containing trough. For materials which will allow of high temperatures and are not injured by the products of combustion, this type of stove is particularly economical in fuel and labour. The danger of overheating and of not allowing sufficient air current to carry off the vapour have to be carefully safeguarded against in the design and working.

Continuous Feeding and Discharge.—Drying cylinders are essentially continuous in their feeding, drying, and delivery, as will be apparent from the various types described later. The materials generally gravitate from the storage hopper or bin down a shoot into the receiving end of the cylinder. Where the materials are suitable, however, a worm feed gives more control over the quantity, and ensures more regularity (see Fig. 106).

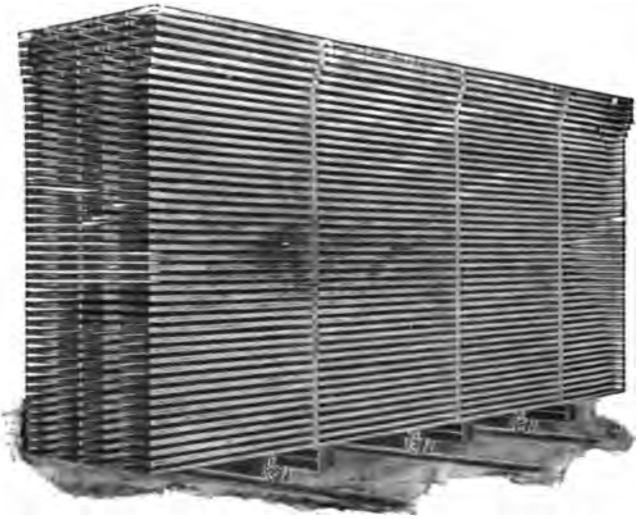


FIG. 68.—TIMBER TRUCKS. CROSSWAY LOADED.
(Erith's Engineering Co., Ltd.)

When the material is in the cylinder the rotation lifts it, and as it drops tends to move it forward. This would slowly deliver the material to the discharge end, but to increase the speed the cylinder is sometimes inclined at about 1 in 12. Ledges or shelves are also affixed to the inside of the cylinder in some instances to increase the lift, and by being spiral may increase or decrease the rate of discharge. Fig. 99 is an

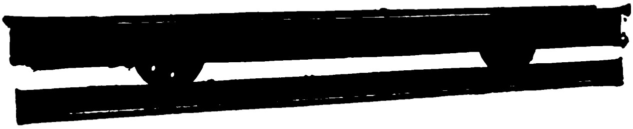


FIG. 69.—UNDER-CARRIAGE OF CROSSWAY TRUCK.
(Erith's Engineering Co., Ltd.)

instance of a horizontal cylinder where the material is propelled forward by the special arrangement of the blades on the inner tube. Their angle can be varied to suit special materials and speeds.

The handling in cylinders thus becomes completely automatic and self-regulating according to the speed of the cylinder, besides which the continual moving brings the material repeatedly into intimate contact with the hot current, thus increasing the vaporisation and the removal of the vapour. A well-designed cylinder offers the most economy in labour and fuel obtainable for materials which allow of the treatment. In some cases the treatment is particularly beneficial to the materials, as in offal, fish, &c., which gradually disintegrate, and by the time they are discharged form a mealy, dry, and even sample.

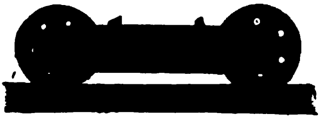


FIG. 70.—CAR BOGIE OF ENDWAY TIMBER TRUCK.
(Erith's Engineering Co., Ltd.)

Intermittent Progressive Feed. — Tunnel drying offers every facility for continuous progressive feeding, drying, and discharging. With lumber, bricks, &c., the movement is intermittent, as the materials are placed upon trucks, and the discharge of one truck leaves the space for the incoming of another at the receiving end, the whole of the loads progressing forward by one car length. The trucks used for lumber and timber are of very simple and economical design. They consist, as shown in Figs. 68, 69, 70, and 71, of truck wheels running in neat ball bearings, and held together by channel bars on each side of the wheel cases. Fig. 68 shows a set of three loaded crossway piling car bogies, similar to the single one shown in Fig. 69, while Fig. 71 shows a set of four loaded endway piling car bogies similar to the single one shown in Fig. 70. With one of these bogies on each rail of the tramway, the lumber or timber serve as stretchers, and the greater the load the more rigid the structure. By placing the timber in spaced layers with distance strips between, the hot air is allowed free and uniform access, thus the drying being evenly gradual throughout each portion, no warping or cracking is likely to occur.

For soft bricks the materials are no assistance in loading the car, which accordingly is built up, as shown in Fig. 72, of steel channels and angle bars. The angle bars form ledges for the pallet boards of bricks to rest upon, and thus present a strong open framework, giving but little obstruction to the heat and air currents. The under-carriage of steel channels, with steel axles and truck wheels running in ball bearings, makes a light, very strong, and easily propelled vehicle for heavy loads. For stiff bricks which can be "hacked" four or more rows high on deck platforms as they leave the press, other types of cars are used. By slightly inclining the rails of the tramway through the tunnel towards the delivery end, the passage of the trucks is facilitated, and the stout, solid buffers of the under-carriage take the strain without any jolting of the bricks.

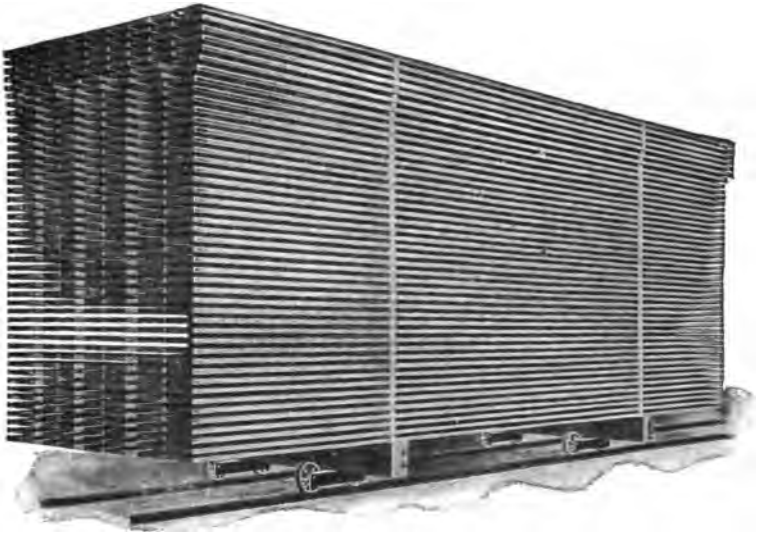


FIG. 71.—TIMBER TRUCK. ENDWAY LOADED.
(Erith's Engineering Co., Ltd.)

A *bogie truck* specially designed to work in connection with peat gantries, but equally convenient for tunnel loading and unloading where the materials are on pallets, is illustrated in Figs. 73 and 74. Here the under-carriage, being built up as usual with steel channel bars and having the usual steel axles and wheels running in ball bearings, has above it a second frame. This frame carries the pallets, and by means of the hand-wheel and levers working by screw, can be raised and lowered. When being loaded it is lowered. When ready to run into position in the gantry or tunnel it is raised; the pallets are thus held just above the supports or horses of the gantry. When in position the frame is lowered again, leaving the pallets on the supports and the carriage free to be removed. After drying, the reverse course is followed, the truck being lowered when run into

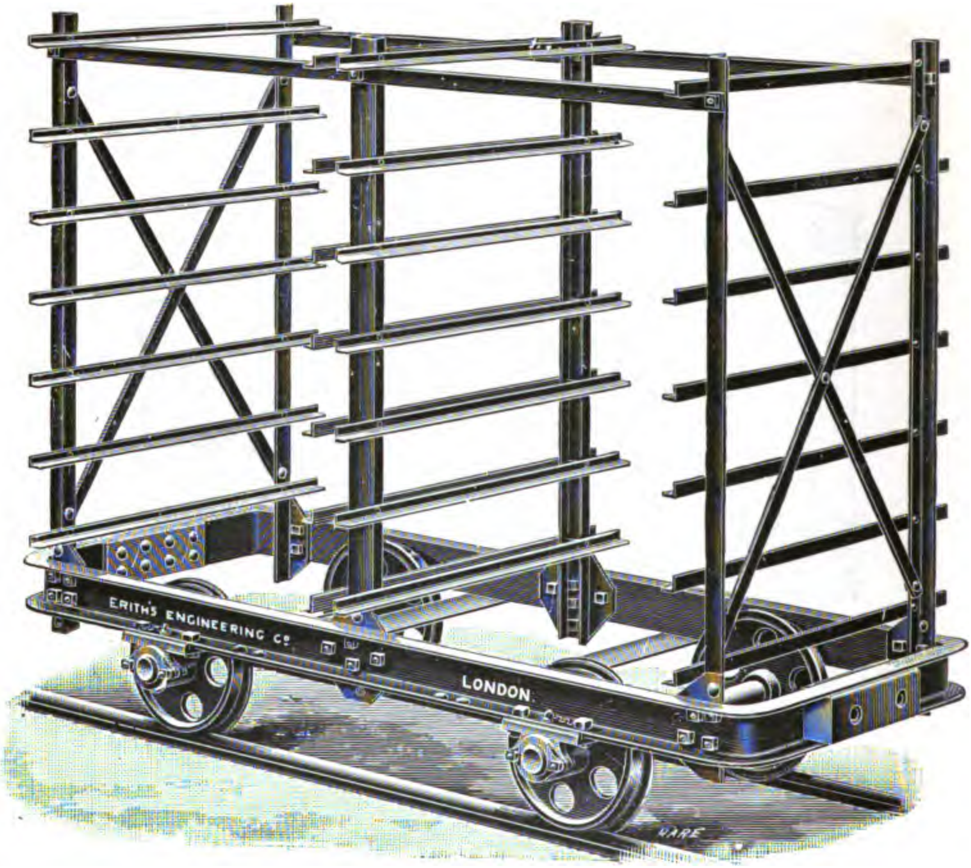


FIG. 72.—BRICK TRUCK FOR PALLET BOARDS. BUILT UP STEEL. (Erith's Engineering Co., Ltd.)

position under the pallets, and on turning the hand-wheel the frame rises, carrying upward the pallets free of the supports. The carriage being hauled away carries its burden of bricks on the pallets.

Conveyor Bands.—Tunnels are convenient passages for conveyors of various types. These conveyors may carry the materials in a state of relative repose on trays or plates, or in perforated buckets, through the tunnels, while the hot air performs the operation of drying. The conveyor is then charged in the manner usual for the particular type of conveyor, before entering the tunnel, and is discharged or automatically discharges itself at the delivery end. Thus the tunnel may be kept at a uniform heat continuously, either throughout its entire length or progressively hotter and colder as the material requires. This offers special economical advantages for materials which do not permit of the usage entailed by a cylinder dryer,

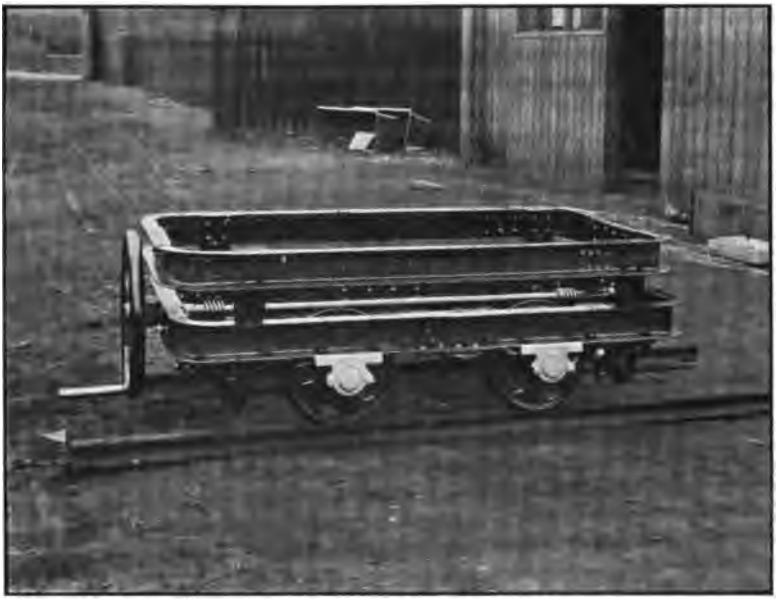


FIG. 73.—LIFTING-BOGIE TRUCK (PATENT). RAISED.
(A. B. Lennox.)

but the air contact is more difficult to obtain in such an intimate and close manner as with cylinder dryers. The labour and handling are practically the minimum possible (see Figs. 80 and 81).

Paddle Conveyors.—Paddle conveying by open spiral or by paddle blades on steel shafts can also be economically used in tunnel dryers for material suitable for such treatment. This method has the advantage over the band and bucket conveyors previously mentioned, of increasing the contacts of the air and heat with the material, thus economising time and heat. Naturally it takes more power than the band conveyor, but not excessively so, unless the conveyor is of undue length. Granular materials are usually suitable for this method, but not those likely to "cake" or paste up, while there must not be a large amount of water, as this is essentially a method for solids. It is possible to greatly accelerate the vaporisation by having

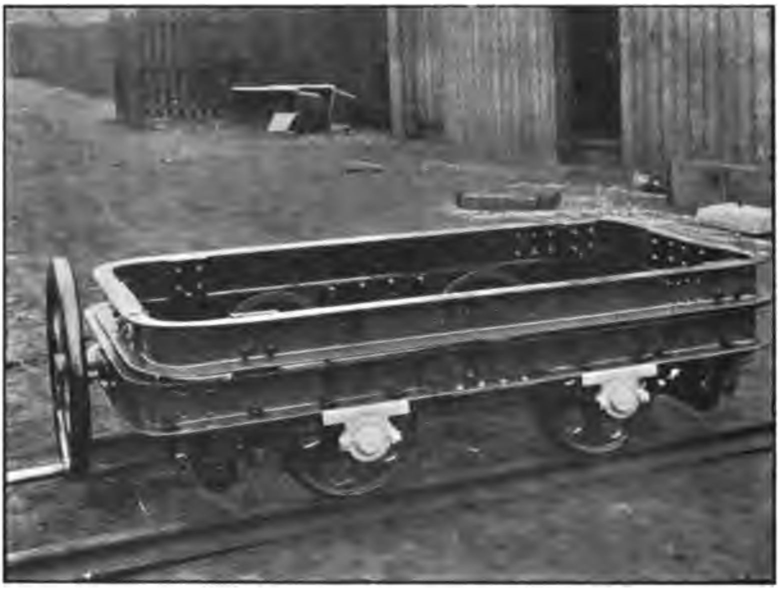


FIG. 74.—LIFTING-BOGIE TRUCK (PATENT). LOWERED.
(A. B. Lennox.)

the heat passed under the trough of the conveyor, either in a jacket or free, also by passing the heat through the shaft and the blades, as well as over and amongst the moving material. It is particularly necessary to ensure that there be a keen air current to carry off the vapour thus generated (see Figs. 151 and 152).

Runways.—For goods which require hanging, tunnels allow of runways being used to considerable advantage, either on the batch or continuous method. These usually consist of the single rail type, supported by brackets from the walls or hangers from the roof. On the rail runs a light bogie with ball-bearing castors, and a hook or other suitable fastener for the material, similar to those now in use in abattoirs and many works for light transportation purposes (see Fig. 76). These generally entail a certain amount of labour, but the construction lends itself to considerable economy in this respect.

In some tunnel dryer installations the barrow is still the means of transport used, and the goods are placed by hand, and after drying hand removed, but this does not obtain the best or most economical results from the tunnel construction.

Manual Labour.—Drying-rooms, in the restricted sense applied to rooms for purposes of classification in this work, are essentially loaded and unloaded by manual labour. Except for temperatures so low as to admit of labourers entering during the process, they are necessarily worked by the batch or fixed charge, but even for low temperatures they are usually batch working. Hence the handling of charging and discharging is mostly manual or by barrow, and the material is generally stationary during the process. Large and awkward goods to mechanically handle are more appropriate to this procedure, and in some measure counterbalance the extra labour, and the objectionable nature of the labour, besides the loss of time and fuel necessarily arising from the method.

Dry-Horses.—Drying ovens offer all the facilities for handling mentioned under tunnels, together with the advantage of being more compact and hence less costly to construct and to heat. With ovens, removable shelves and trays forming practically self-closing drawers may be economically and conveniently used to handle the material. The outer casing may be constructed in sections and withdrawal in panels. These panels may be built up into "horses" or light gantries, as shown in Figs. 75 and 76, for laundry and dye-house purposes. By the light runway shown at the top of the vertical section the whole panel can be readily withdrawn or closed without interfering with the remaining sections. In this particular case the heating is by steam pipes from below and the vent by a downward return, but this is irrespective of the method of handling, and the arrangement is capable of an indefinite number of variations to suit the other aspects and requirements of drying. For instance, a track may be on the floor instead of the runway and the panel have light running castors under it. In some cases the panels are entirely removable, and being interchangeable can be replaced while being loaded or unloaded.

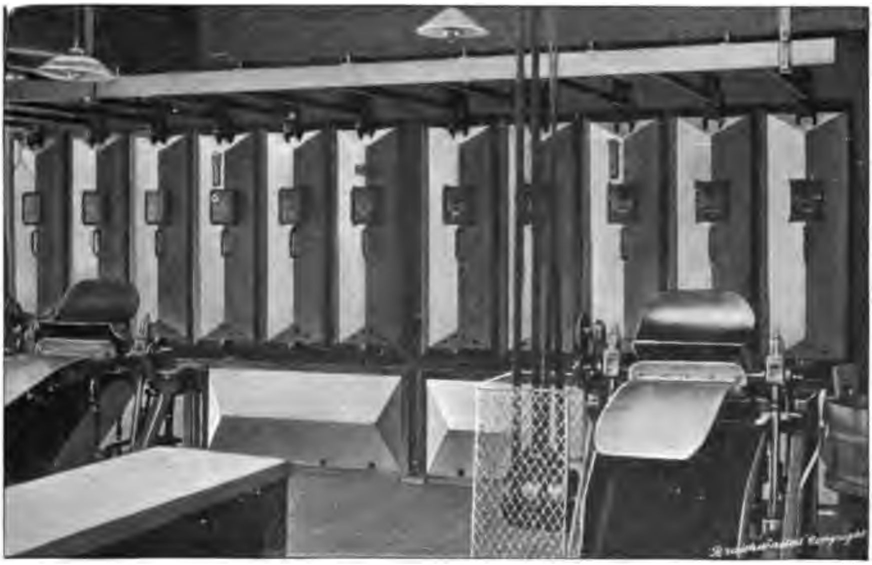


FIG. 75.—DRY-HORSES ON RUNWAY. EXTERIOR VIEW.
(I. Braithwaite & Son, Ltd.)

Frame Conveyor.—A form of conveyor used in connection with pottery ovens has a vertical shaft rotatable in the centre of the oven. On this shaft is a cylindrical framework nearly as large as the room. The framework is built up of radial arms from the shaft, and a circumferential series of shelves made of wooden laths or strips. The person charging this stands at the entrance and takes off the vessels dried and replaces them by the moist ones, then rotates the whole frame sufficient to bring the next series of shelves opposite the entrance and replaces their contents. Again he moves the framework round to the next series and so on. As the whole is swung on the central vertical shaft and carries a fairly uniform load throughout, it is comparatively easily moved the several stages. This considerably lightens the labour and secures more regularity in charging or discharging than having shelves round the drying-room. Further, it saves loss of heat and time, besides obviating the objectionable working in the room.

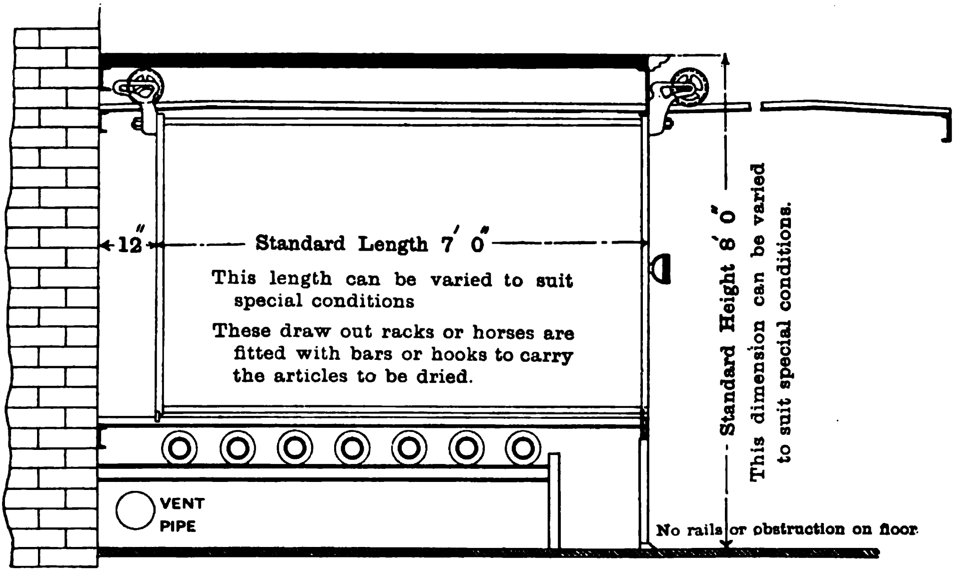

12"
Standard Length 7' 0"
This length can be varied to suit special conditions
These draw out racks or horses are fitted with bars or hooks to carry the articles to be dried.
Standard Height 8' 0"
This dimension can be varied to suit special conditions.
VENT PIPE
No rails or obstruction on floor

FIG. 76.—DRY-HORSES ON RUNWAY. SECTIONAL ELEVATION.
(I. Braithwaite & Son, Ltd.)

Safeguards.—Autoclaves, as essentially self-closing and working under pressure or vacuum, are only suitable for batches. Generally a double track of rails is laid in the autoclave for the material, whether timber, bricks, &c., to be passed in and out on trucks. The entrance is then closed and the pressure completes the seal, the material remains stationary till the drying and other operations are completed. In some instances the exit is by similar sealed doors at the other end, especially is this so in those autoclaves used for disinfecting, as thus the disinfected goods run no risk of being contaminated by contact with the infected goods or infected atmosphere (see Fig. 171).

Desiccating dryers are worked by batch or continuous according to the material and the conveniences of the particular method. For instance, the vacuum desiccator illustrated in Fig. 162, by a careful adjustment of the feed and delivery valves, works with a continuous inflow of the liquid and a steady output of desiccated powder. Necessarily the details of the glands around the revolving shafts have received the consideration of the designer and the utmost care of the manufacturer.

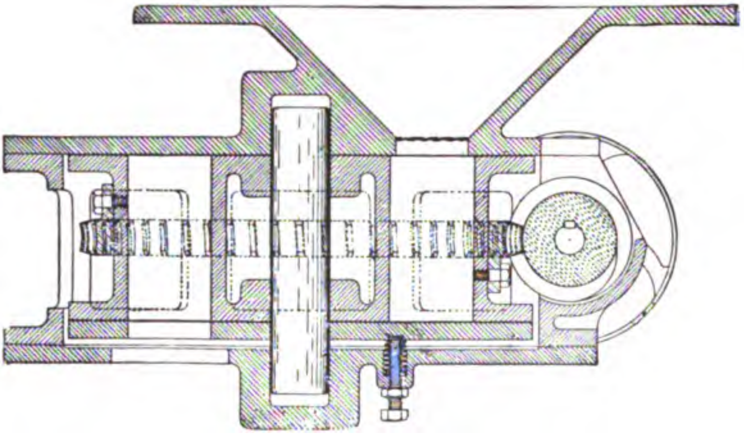


FIG. 77.—AUTOMATIC ROTARY VALVE FOR VACUUM APPARATUS (PATENT). SECTION.
(Geo. Scott & Son, Ltd.)

A mechanical valve for this purpose is illustrated in Fig 77. This consists of a drum rotating round a central spindle, and provided with two or more pockets. The faces of the drum are faced and scraped true to avoid any leakage of air into the vacuum apparatus. The rotary valve is put in motion by a belt usually from the vacuum pump of the dryer.

Dip Feed.—In a desiccator for milk and similar liquids a continuous action is maintained in the following simple but effective manner. The liquid is kept uniformly level in a shallow pan, while a revolving hollow cylinder just passes deep enough into the liquid to have its periphery wetted. As the cylinder continues its revolution, the wetted portion becomes dry by evaporation, as there is steam inside the cylinder. The cylinder being of considerable circumference, the liquid is dried and desiccated into comparatively loose powder before the same portion of the periphery reaches the containing vessel to be again wetted. At the stage of its revolution where the dried material has attained the dryness required, it meets a wiper or scraper which guides it away to a proper receptacle. This machine gives an effective desiccation of delicate materials with the minimum of handling or risk of contamination or loss. At the same time, if the volatile matter is of value it can be readily withdrawn and condensed in a coil. Similar method of feed is used in the Wilfley Dewaterer (see Fig. 9), and in a somewhat modified form by a feed roller which dips into the supply of many other machines.

Panelled Racks on Double Track.—Fig. 78 shows a type of panelled rack specially designed to deal with yarn on reels or swifts, but adaptable for similar purposes. Here the rack is on a double track laid in the floor, for carrying heavy loads, and has large runner wheels. As each end of the rack closes the aperture in the drying oven or closet, there is no loss of hot air while loading and unloading. The working can be continuous or batch, as preferred. The usual heat supply is by the heated air through a special distributor pipe (see Fig. 51) at the top of the oven, under pressure, and the moisture is driven out at the bottom.

Superimposed Band Conveyors.—Conveyors are very adaptable means of handling many kinds of materials while drying, as they offer great facility for applying the heat and removing the vapour as well as automatically transporting the materials or goods during the process. They can handle most delicate materials or the weightiest by modifying the shape or character of the carrying medium, of which several instances appear among the installations described, especially in tunnel dryers.

The illustrations (Figs. 79 and 80) give a typical instance of the economy of space which can be obtained by conveyor, and the "lofty" nature of the handling they give to wool or other fibrous material.

The three superimposed conveyors are each endless canvas webbing running over light metal rollers, thus requiring the minimum power, and producing practically no friction. The material automatically delivered by the feed roller on to the top conveyor is airily transmitted without any pressure through the heated air current, and lightly dropped on to the second conveyor, which transmits, and in due course delivers, to the third conveyor.

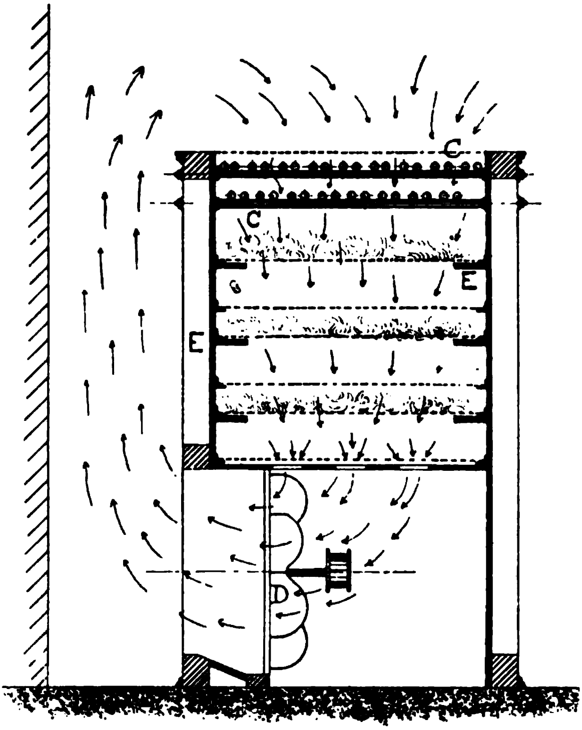


FIG. 79.—BAND CONVEYOR DRYER. TRANSVERSE SECTION.
(W. Summerscales & Son, Ltd.)

The third conveyor drops it into a hopper which is aspirated in a manner to automatically carry the wool or other material from the dryer to wherever it may be required. This design of aspirating conveyor is illustrated in Figs. 117 and 118, and further described on page 206, in connection with a dryer using this action during the process.

For piece goods which need stretching while drying the *Drying and Stretching* machine (Fig. 81) shows a simple automatic continuous method of handling. A stout cast-iron framework has an endless chain along opposite sides. The two chains have pins or spikes which attach to the selvages of the piece, and while drawing them along also hold them taut. When passing the first portion of the traverse the cloth is simultaneously stretched and damped somewhat by steam. During the remainder of the passage the piece is held taut, and a strong heat is

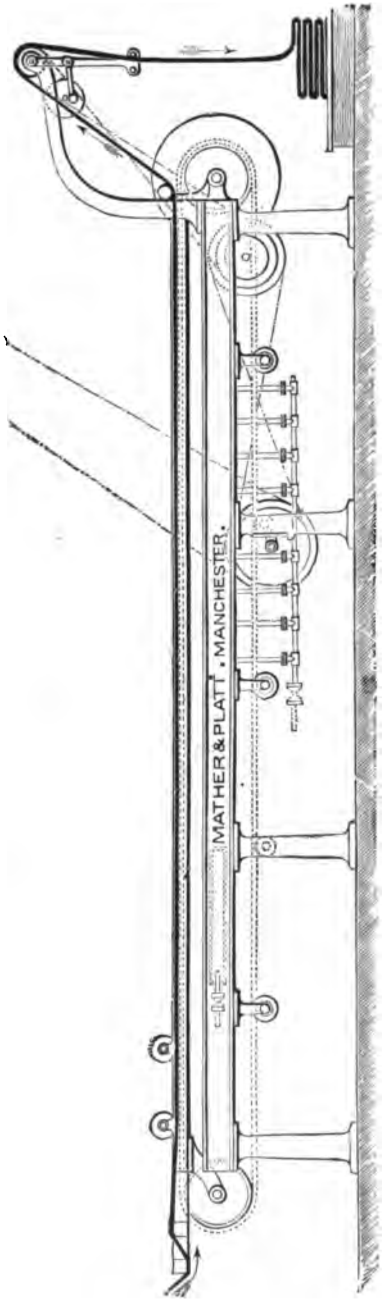


FIG. 81.—DRYING AND STRETCHING MACHINE.
(Mather & Platt, Ltd.)

applied by gas jets on the under side. Thus the cloth is dried rapidly with a "feel" on one side and evenly stretched throughout its width and length. It will be seen that the machine is belt driven through step pulleys, allowing of several speeds of transit to suit various cloths. The endless chains pass over the usual terminal rollers and carrying rollers on the lower side. The cloth is guided into the machine and pressed on to the pins of the chains by small indiarubber covered rollers or brushes. The delivery of the cloth in layers or folds is performed by the plaiting arrangement worked to and fro by a crank motion. The steaming attachment can be seen in dotted outline at the receiving end, while the gassing gear is visible nearer the delivery.

A simple and effective method of *handling hanks of yarn* when passing through a roller or cylinder dryer is shown in Fig. 110. The hanks are connected into a series of continuous bands. The end of each hank is connected by means of an improved brass coupling link to the end of the succeeding one, thus forming a built-up band. The links keep the yarn even and readily pass round the cylinders in a uniform manner.

From the various instances given above, and others which are described under the installations, it will become apparent to the student that the factor in handling of materials is the nature and condition of the material itself. Thus in all its aspects as to heating, vaporising, abstracting the vapour, and handling the material, there is the same factor to consider as the basis of working. Hence the vital importance of having a complete knowledge of the *idiosyncrasies of the material* before fixing on a method of drying. It has to be borne in mind that the idiosyncrasies in the same material differ in kind and degree with almost every variation of wetness and temperature, while they generally become most prominent and sensitive as the final stages of drying proceed. They must be viewed from all points and at all stages, if a successful method is to be chosen. Afterwards the machinery to carry out this method should receive consideration with due regard to cost, economy of labour, fuel, and time.

CHAPTER VIII

EVAPORATIVE DRYING INSTALLATIONS

Classification—Data Necessary for—(i.) General Inquiry; (ii.) Timber Plant; (iii.) Brick Plant - - - - - - - 157-160

Drying Floors.—Natural—Artificial—Advantages—Disadvantages—When Used - - - - - - - - - 160-163

Drying Gantries and Racks.—Purpose—Construction—"Sow" Method—Richmond Racks—Wet Clothes—Sheaves of Wheat—Peat—Pigments—Rubber—Bricks—Chalk—Explosives—Crucibles—Clayware—Pallets—Waste Heat—Fish Smoke-Rooms—Spits - - - 163-166

Drying Sheds.—Nature and Use—Examples—Disadvantages - 166-167

Drying Pans and Troughs.—Purpose—Examples—Salt Pans—Johnstone Agitating Pan—Newhall Conveyor Trough Dryer—Universal Vacuum Trough Dryer - - - - - - - - 167-172

Classification.—There are so many types of drying plants, and such a variety of those types, that for convenience of classification and remembrance the following arbitrary classification has been made so far as regards the appliances and installations here described. The idea underlying this classification is to differentiate the various installations working on evaporative principles according to their essential and characteristic features.

1. *Drying Floor:* used in those cases where the material remains on the floor during the drying processes.

2. *Drying Gantry:* used where during the drying processes the material is supported on an open framework (whether in vessels or not).

3. *Drying Shed:* used in the restricted sense of being a covered space open to the natural air currents of the surrounding atmosphere as contrasted with drying-rooms.

4. *Drying Pan:* a metal vessel with open top or air inlet allowing the aqueous vapour free egress to the surrounding atmosphere.

5. *Drying Kiln:* a building containing a furnace or com-

bustion chamber, the direct heat of which dries material in the same chamber.

6. *Drying Stove:* a combustion chamber or furnace in which the material is dried, but is a vessel or receptacle, and so removable as contrasted with a kiln.

7. *Drying Cylinder:* when the drying portion of the apparatus is essentially cylindrical for facility in revolving. It is not used where a stationary dryer of any kind is merely cylindrical in form.

8. *Drying Tunnel:* restricted to those installations where the material passes through a building on trucks or conveyors during the process of drying.

9. *Drying Room:* an enclosed chamber (as contrasted with shed) in which there is no furnace, and into which it is necessary to enter in placing or displacing the material to be dried (as contrasted with ovens).

10. *Drying Oven:* an enclosed chamber or receptacle in which there is no furnace, and in which it is not necessary to enter in order to place or remove the material to be dried.

11. *Desiccator:* a drying machine in which the process is continued to such a degree as to abstract all the water in the substance which is not actually chemically combined in its molecules.

12. *Autoclave:* a vessel which performs drying as part of the process of other operations under pressure or vacuum.

Data to Send when Inquiring.—From the facts now examined, it is quite evident that choosing a suitable dryer demands a full consideration of all the surrounding circumstances as well as an intimate knowledge of the material itself. When communicating with the makers of drying machinery it will save time and correspondence to send the following particulars:—

1. As to the material.
   - *a.* The nature as to the heat permissible.
   - *b.* The condition when put into the dryer whether in liquid, semi-liquid, or solid state.
   - *c.* If solid, the sizes and weights of the portions.
   - *d.* The amount of wet material to be dried per day.

- *e.* The amount of water to be removed.
- *f.* The condition desired to be obtained. If it be possible, send samples of the wet and the dry material; put them in air-tight and water-tight boxes.
- *g.* Any special risk which has to be avoided.
- *h.* Would products of combustion be injurious to the material, say from coal, coke, oil, or gas furnace?

2. As to the facilities available.
   - *a.* A sketch plan showing outline of the present building, the engine, boiler, and motive power where any exist.
   - *b.* The amount of live or exhaust steam available, and the steam pressure.
   - *c.* The motive power, kind and amount available.

The inquiry forms given below are particularly convenient for their respective purposes, and are those published by the Erith's Engineering Co., Ltd.

When inquiring for *Timber Drying Plants*—

1. What quantity of wood do you want to dry daily?
2. Will you work the dryer night and day, or in the daytime only?
3. Give full description of wood or woods.
4. Is the wood green from the saw, or partly air-dried?
5. What is the usual thickness and length of boards, deals, staves, &c.?
6. Do you wish us to furnish a suitable low-pressure steam boiler?
7. If exhaust steam is available, give approximate horse-power of the engine.
8. What is the heating surface of your boiler (or, preferably, how much water does it use per hour), and what is the pressure carried?
9. What fuel will you use for your boiler?
10. Send a rough sketch of position available for dryer building, showing distance from mill, boiler, &c.

When inquiring for *Brick Dryers*—

1. What make of brick machine do you use?
2. What is your daily production?

3. Will the bricks hack up, or must pallets and rack-cars be used?
4. Is your clay porous, plastic, shale, marl, or fire clay?
5. Do your bricks crack when subjected to wind and sun?
6. State dimensions of green bricks, or other product.
7. State the weight of a green brick.
8. State the weight of a dried brick.
9. Give description and size of your boiler, and state steam pressure carried.
10. Give description and indicated horse-power of your main engine.
11. Will you use exhaust steam in the dryer at daytime, and live steam at night; or live steam only?
12. Do you desire to use waste heat from kilns? If so, state description, number, and size of kilns.
13. Send a rough sketch showing relative position of brick machine, site for dryer, boiler, main engine, and kilns.

Drying Floors.

Natural Floors have the advantage of entailing but small initial outlay, and requiring slight, if any, repairs. As means of drying by evaporation, all the floors have serious disadvantages as to heating, removal of the vapour, and handling. The heat when from above takes an undue time to permeate the mass, and from below has a cooking and caking action. The dispersion of the vapour in the first case is retarded by the cold body below, while in the second case it cannot commence till the mass is heated through, and even then the hottest part is not exposed, so all its vapour has to pass through the upper material. The handling obviously entails placing upon and removing from the floor, but owing to the uneven distribution of the heat it also entails the stirring up or turning over of the material one or more times if time and fuel are to be saved. The cost in space, too, has serious disadvantages where large bulks have to be handled and ground expensive.

Of heating from above, *haymaking* is a good instance, and one in which the disadvantages are apparently unavoidable, while the sun's heat is free when available. Haymaking is also a good illustration of the governing principle of all drying installations, which is that the material governs the method of drying, and has to be considered more than mechanical efficiency. The nature of grass makes haymaking in many ways a particularly interesting case of drying. An artificial method of haymaking for use in wet summers is described under Drying-rooms (Gibb's).

Brick drying by the sun's heat on earth floors has doubtless always been practiced more or less, but its disadvantages are so obvious that no modern brickyard would consider it, even if competition would allow. If sheltered from the direct heat and carefully placed to ensure even circulation, of course air-drying is not so objectionable nor quite so likely to cause cracks, but the time taken and the uncertainty of action in our climate are serious impediments to its use.

The loose piling of *peat blocks* to assist the drainage and further dry is in extensive use. With propitious weather and unlimited time the result is satisfactory and cost small. But to compete with coal or other fuel time and handling must be curtailed by gantries or other means (see Fig. 65).

Artificial Floors.—The use of artificial floors warmed by the products of combustion from a furnace, by hot gases, live steam, or exhaust steam passing in flues or pipes beneath, is a considerable step on the above. These floors are in much wider use mainly because of the small initial outlay, the simplicity of working, and the absence of any need for motive power. Given a good supply of fuel or steam and unstinted labour they give a good sample for such materials as china clay, barytes, cement slurry, ground calcined quartz, chalk, fuller's earth, ground phosphates, &c. These require draining as well as drying, and do not readily injure by an excessive or irregular heat.

In constructing these drying floors it is usual to take advantage of any convenient sandy or porous ground floor. If the natural ground is clayey it is found economical to put down a foot or more of sand; this acts as a bad conductor of the heat and as a good drain for the water. On this put a number of flues formed by side and division walls of brick covered by porous tiles. Having a furnace at one end the gases pass through the flues and up a chimney at the far end, or when steam is used the pipes pass along the flues. The sand and porous tiles in most cases do the bulk of the drying by drainage, while the heat completes the process. In either case it is necessary to turn over the material to save time and heat; especially is the movement necessary when the material is of a cloggy or caking nature. As this is a batch process it is usual to divide the floor into compartments by division walls so that a compartment can be emptied while another is filled. In those direct fired, the ends near the fire naturally do their work quickest and need extra strong tiles.

When used at the *china clay works* the wet material generally contains 50 per cent. of water, and the dry product should not contain more than 5 per cent. It is usual to dry about 10 tons of clay with 1 ton of coal. Locally the floor is called a "dry." The material is put on in a 6 to 9 inch layer.

This type of floor is used for the unground *phosphate of lime* in parts of France and Morocco, but the tiles are replaced by iron plates and the material frequently shovelled over to hasten the operation. Sometimes a mechanical stirrer is used where power is available.

Wet *barytes* is thrown from the settling tanks as a stiff paste with about 25 to 30 per cent. of water on to similar floors and left till it is dry enough to cohere sufficient to be cut into bricks, when it is removed to the drying kilns.

Chalk is allowed to remain in the settling tanks till it can be just handled. It is then placed on somewhat similar floors in peculiar brick-like chunks. When partially dried these chunks are stored on a rough gantry to air dry.

By the *wet process of cement manufacture* the cement slurry is pumped in a thick creamy stream containing about 33 per cent. water on to floors of cast iron over direct furnaces and left in a layer of about 6 in. till quite dry. It cakes to a considerable extent but on removal crumbles somewhat.

The *ground calcined quartz*, used as the abradant in some of the special polishing soaps, is thus dried. As it discharges from the wet grinding mill it runs down pipes into similar floors heated by exhaust steam. The handling is a costly item owing to the excessive fineness of the powder.

Other drying floors are used in kilns, and various mechanical stirrers are adapted for different kinds of material. See under Kilns and Methods of Handling Materials.

Floors *per se* do not give sufficient surface exposure to get efficient vaporisation or dispersion of the vapour.

Drying Gantries or Racks.

Purpose.—The purpose of Gantries is increased surface exposure, so that the air currents can have access to every possible inch of surface.

Construction.—They assume various forms, as skeleton shelves, racks, props, &c., according to the nature and condition of the material. They are simply the means of supporting the material to the best advantage, and may be quite independent in the open or form part of the apparatus of drying kilns, drying stoves, drying tunnels, drying rooms, or drying ovens.

Hot water and *steam pipes* are occasionally used as gantries or racks for supporting materials while drying, but are only permissible when heating by conduction and for materials which are not injured by local application of heat. Generally their use as racks is to be avoided as uneconomical and tending to produce uneven drying even where distortion or surface deterioration do not arise.

A striking illustration of the efficiency of surface exposure on a very frail gantry is that of *wet clothes* on a line when it is freezing. Even when the temperature is so low that the water in the clothes freezes into a stiff sheet of ice, the amount of surface exposure will evaporate all the moisture and the clothes become perfectly dry if there be a good stiff wind.

The *sheaves of wheat* and other grain, leaning against each other when "stooked" in the harvest field, form a temporary gantry which greatly accelerates the drying by permitting the free circulation of the warm air to all the surface.

The "*Sow*" *method* used at harvesting when the weather turns wet makes a useful rack of the loose fence rails (hurdles). A double row is sometimes formed with the rails inclined so that their tops touch each other, while at the foot they are about 2 ft. apart. Then the sheaves are built on the sides, so that their heads are inwards, thus sheltered from the rain but exposed to the winds. Sometimes a long hollow wooden skeleton frame is built temporarily for the same purpose. The sheaves are in this case placed with their heads inwards, and form their own shelter from the rain. They are used chiefly in Scandinavia and other northern countries.

Richmond's racks are contrivances by means of which the sheaves of damp corn may be stored in thin layers, so arranged as to induce the play of air currents, and thus expose the sheaves to the drying influence thus created. In the original form they are about 100 yds. long by 5 ft. wide, and about 16 ft. high, built of stout upright straining posts and wires about 8 in. apart throughout the length. The wires form rests for the sheaves; these are laid above each other into a wall-like structure, which is covered by a light top. Such a structure offers great facility of handling and drying. Generally dries its load of about 20,000 sheaves in a few days. It can be used continuously as the corn is cut, and saves considerable space at little first cost.

A similar construction is sometimes used to form *an open shed* by having two racks at about 20 ft. apart, and putting a light galvanised roof over the two racks and intervening space. Thus the sheaves form the side walls of the shed, and having their heads turned inwards the corn readily dries, while leaving a convenient covered shed between.

In drying *peat* on the bog use is made of gantries constructed of wood. These support pallets six tiers high, on which are placed in open order the wet bricks of peat. A free passage for drainage during "unwatering" and for the air during the drying is thus ensured, while the sun can get ready access all round the tiers. This method saves much handling, besides increasing the efficiency (see page 139).

An open gantry of skeleton shelves, built up of wood scantling, about 3 in. by 3 in., is used to hold the vessels containing the *pigments* at colour works. This enables the heat and air to obtain surface contact with the vessel and the colour, thus assisting the evaporation at all points.

A rack of wood scantlings about 1½ in. by 3 in. is used for hanging raw *rubber* sheets and crêpe after washing. The rack must be well supported about 8 to 10 ft. high, and the laths are generally about 6 in. apart.

The *chalk* in rough brick-like chunks is placed on an open rack work to dry by air currents when desired in a soft smooth condition. This gradual rack process is very slow, and dependent on the atmospheric conditions, but users appreciate the absence of the "harsh caked" nature of the more rapidly dried. The sample is more even throughout, and it has not "cooked."

Gunpowder and other *explosives* are often "sun-dried" or "air-dried" on wooden frames, over which are spread out canvas sheets similar to filter cloths. The sample is much more friable than that more rapidly dried. The rapid drying of these mixtures has a tendency to cause a partial separation, as the nitre is carried to the surface and tends to cake over. Channels and cracks are made in the grains, impairing their density, increasing their bulk, and rendering them more hygroscopic. The dust forms a larger percentage than when dried more slowly.

In steel works, after the *crucibles* are moulded, they are placed on light gantries of wood in the cellars, where the furnaces get their draught. They remain about three days in this gradual drying chamber, and are then removed to a gantry of light shelves over the top of the furnaces. Being placed about 8 to 10 ft. above the furnace, they are not subject to any great heat, but a gradual thorough drying for about four more days. The crucibles are then uniformly dried and slightly heated throughout their substance, ready for putting into the ovens to be finally baked.

Racks are used in many ways for the drying of *bricks* and *clayware*, generally in connection with pallets. For instance, with plastic bricks pallets of wood holding six or eight bricks are filled by the moulder. These pallets are plain pieces of 1-in. wood wide enough and long enough to hold the bricks with ½ in. clearance between each brick. Strips are placed at the end, so that the pallets can rest on each other without crushing the bricks.

The loaded pallets are placed on barrows or trucks to transport them to be dried and afterwards to the burning kilns. The trucks are generally of the type shown in Fig. 72. Where the framework forms a rack for the pallets and where tunnel dryers are used, no further handling is needed, although in some cases the trucks are so constructed that they deliver the pallets on to racks in the so-called tunnel dryers. This method lessens the number of trucks necessary, and saves the heat absorbed in warming the truck, but entails more labour than where the trucks remain in the tunnel.

The loaded pallets are sometimes simply placed one above another, and left to dry by aeration under sheds with or without any additional heat. The heat is sometimes supplied from steam pipes in a trench of the shed floor and the rack built up of the pallets. In this case the pallets are made longer and broader to carry a larger load, and the end strips are stouter accordingly. The bricks, too, are usually placed on end instead of on one side.

In some of the brick sheds racks are built of stout uprights with cross-bars and on these the pallets are placed in nests one above another. This method has been much developed in connection with *waste heat economising sheds*, but the additional labour must go far towards absorbing any saving from the coal consumption. In fact, such sheds only appear worth consideration where fuel is costly and labour cheap.

The smoke rooms or kilns used in fish-drying are also instances of built-up gantries or racks, the " spit " being arranged on the cross-bars of the standards.

Drying Sheds.

Nature and Use.—A roof to keep off the rain and snow is an absolute necessity over drying floors and gantries if they are not to be altogether subject to the weather. This may be lightly built of galvanised iron, and for drying purposes the more open it is on all sides the better, although some materials require to be shielded from light or the direct rays of the sun, for instance rubber, leather, &c.

The sheds covering drying floors, gantries, stoves, and ovens are usually much better if built of light open framing than of more solid brick construction. The removing of the vapour is greatly facilitated and the heat is not lost, having already done all the work advisable. To heat up a room for drying and not allow the vaporised moisture every facility to escape, is really utter waste of fuel. The tendency is then to " cook " the material instead of drying it, and it is well to bear in mind that *vapour is the greatest possible obstacle to further vaporisation.* If the roof be louvred at the top it has additional aspirating effect and is less likely to sweat from the extra moisture. A shed which merely acts as a protection from the rain and snow without any stove is the ideal condition for producing "air-dried" material. The increased selling price in some cases pays for the time and space required, but whether the quality is really any better than a properly designed drying plant would produce is open to much doubt.

These open sheds are used for many purposes, and besides being very low in first cost they do produce an excellent sample of many goods. The time taken and the uncertainty, owing to the varying humidity of the surrounding atmosphere, are great disadvantages, as is also the liability of contamination of the material from smuts, dust, and mildew in the air.

China clay and *ochre* in the quarry state are thus deprived of their quarry water by being piled in open sheds. The roughly cubical clods, as dug, are loosely piled as open as possible to allow the air to pass through the mass. This dries them quite sufficiently for grinding.

In the drier atmosphere of Chili such open sheds are sufficient for the drying off of the *nitrate of soda crystals* without any artificial assistance.

Bricks stacked in piles with hit and miss spacing are often thus dried without any firing in the shed, but it is much more usual and expeditious to have a drying floor under the shed, besides giving more uniform results.

Drying Pans and Troughs.

Purpose, &c.—Drying pans are really very useful appliances for partial drying of "soaked" and "wet" material, but are usually badly designed and worse handled. Pans generally work on the batch principle, which entails extra handling and loss of time to empty, but they need not. The most ancient commercial use, and the one generally associated with pans, is in the evaporating of the *salt brine.* But this is not by any means a sample of pans well applied to their purpose. They occupy large space, are heavy on the fuel, give off objectionable gases, and the wear and tear is very great from the corrosion.

The finer the salt the heavier the coal bill and the heavier the repairs.

A usual *salt pan* is oblong, with 600 to 1,000 ft. of surface and about 12 to 16 ft. deep. Under it are three or more fires, and it stands in its own shed. The firing flues and chimney are arranged as in drying floors, *i.e.*, the furnace is at one end, the flues pass under the whole length, and the chimney is built at the far end.

Shallow flat *earthenware pans* are used in the colour trade, and when carefully arranged on gantries in properly heated and ventilated rooms they are very reliable and efficient. The plan of placing them on each other over a hot floor and providing no means for plenty of air is costly in fuel, wasteful of time, and unnecessarily laborious.

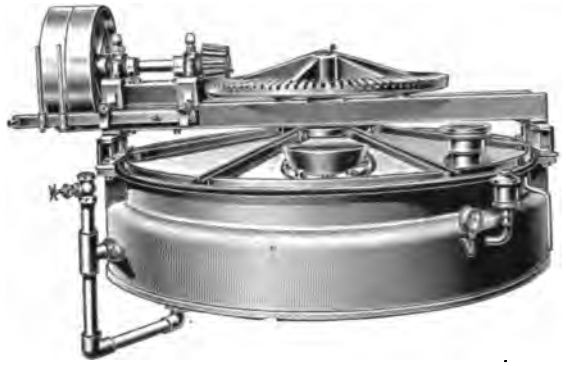


FIG. 82.—JOHNSTONE AGITATED PAN DRYER. GENERAL VIEW. (Manlove, Alliott, & Co., Ltd.)

These *pigment pans* are also used in drying ovens of the alternating shelf type, which give more economical results with less space and less labour.

Semi-cylindrical iron pans heated from below by furnace or by steam, and having the wet material stirred mechanically with a revolving grid, give good results with soft materials, especially powders. The top is open to the atmosphere and the evaporation is very rapid, but the power required is rather heavy when the material is in the intermediate semi-dry state.

The "*Johnstone*" *Pan Dryer*, as shown in the general view, Fig. 82, and vertical section, Fig. 83, consists essentially of a stationary steam-jacketed pan with slow moving scrapers or stirrers to continually agitate the material by sweeping round the bottom and sides. It has an outlet through the bottom with valve for automatic discharge, and inlet for air and outlet for saturated air are at top. The stirrers are generally as shown, but vary to suit material. The vertical shaft working the stirrers may be driven either by the worm gear or the spur gearing, as the motion is slow and small in amount. The top access and bottom outlet allow of the machine, although working on the batch principle, to be filled or emptied while running without manual labour or risk. The agitation of the material and the jacketing of the pan tend to economise the heat, and the steam necessary would be dependent on the proportion of water much more than in a pan with the material stagnant.

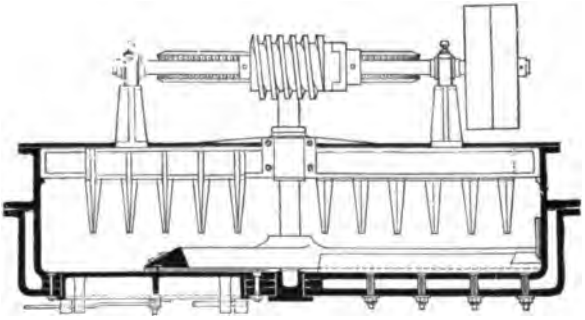


FIG. 83.—JOHNSTONE AGITATED PAN DRYER. VERTICAL SECTION.
(Manlove, Alliott, & Co., Ltd.)

The machines are intended to deal with semi-liquids and dry them to powder. For instance, the 8-ft. size with a pan 20 in. deep and 85 cub. ft. capacity, would accommodate from 20 to 40 cwt. of fish or blood with about 75 per cent. moisture. In about eight hours the machine would reduce this material to a dry inoffensive powder, with about 10 to 12 per cent. moisture, and discharge automatically without any handling. The fan in the meantime is carrying away the moisture for disposal according to its character; for instance, with excreta, offal, condemned meat, or other animal matter, it can pass through a condenser and eliminate all effluvia. Such machines can be conveniently used for distillery wash, thus producing a meal suitable for feeding while soaked, damaged grain is readily improved in condition.

The "*Newhall*" *Conveyor Trough Dryer* is a type of troughed pan used for granulated sugar and similar purposes. The steel plate pan is a deep trough with removable covers, and part air-jacketed. The conveyor has a hollow tube and hollow paddles, into and through which steam passes. The air is forced into the bottom of the material trough through the air jacket, and passing out by a large pipe into a stive room to drop its fine sugar, and thence outwards. The material is fed into the hot end, and automatically transmitted by the paddles to the outlet at the bottom and cool end, thus having ample and intimate contact with the heat, and a plentiful supply of air to carry off the vapour, as will be seen in Fig. 84A, a general view showing the slow worm gear drive, and Fig. 84B, a section showing the hollow shaft and paddles and the partial air jacket.

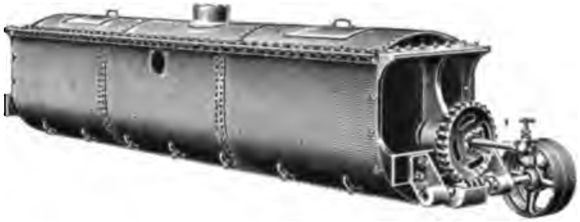


FIG. 84A.—NEWHALL AGITATED TROUGH DRYER. GENERAL VIEW.
(Manlove, Alliott, & Co., Ltd.)

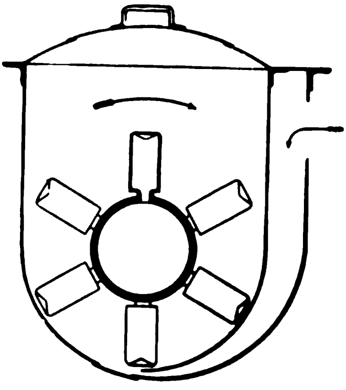


FIG. 84B.—NEWHALL AGITATED TROUGH DRYER. VERTICAL SECTION.
(Manlove, Alliott, & Co., Ltd.)

A machine to evaporate moisture and volatile matter in soft, plastic, or tough masses, while being kneaded and mixed, is illustrated in Fig. 85, the "*Universal*" *Vacuum Kneading* *and Mixing Machine*. This machine consists of a trough, which is of cast iron, provided with a jacket suitable for heating by steam (up to 105 lb. per sq. in.) or cooling by water. In the

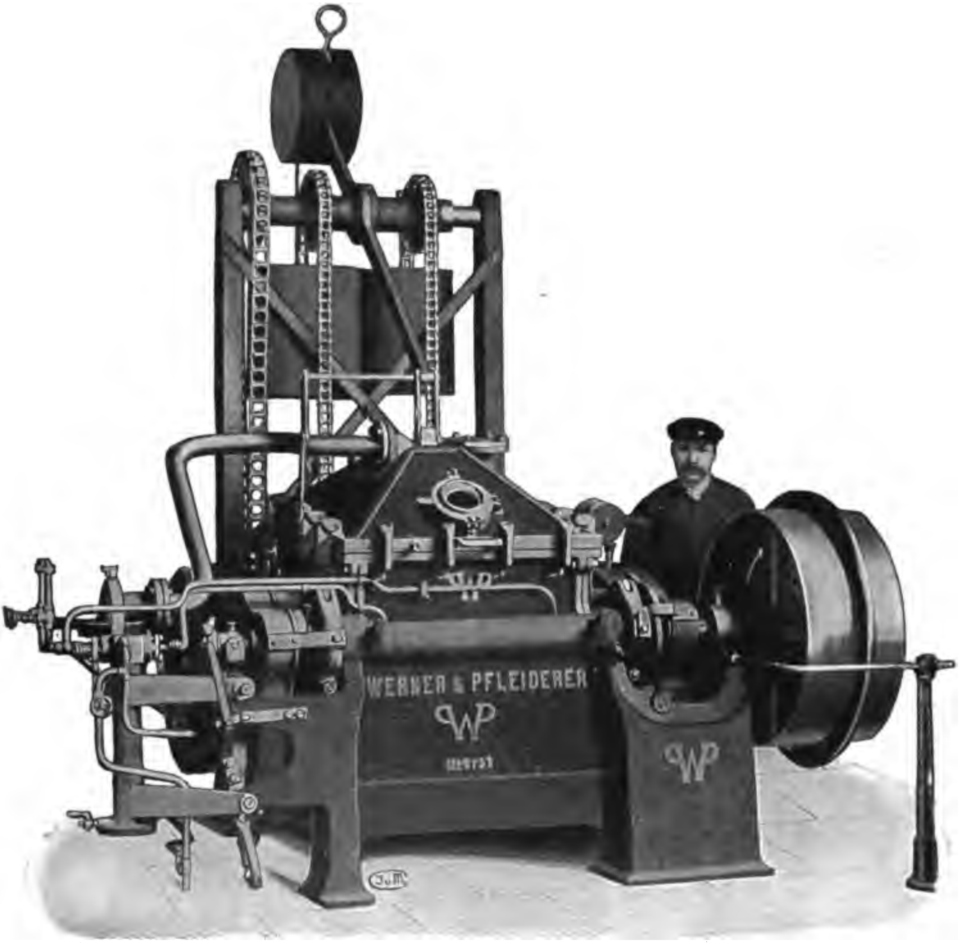


FIG. 85.—UNIVERSAL VACUUM KNEADING TROUGH DRYER. IN WORKING POSITION.
(Werner, Pfleiderer, & Perkins, Ltd.)

trough are revolving kneading blades, which have bearings fitted with patent removable stuffing boxes so constructed that no lubricating oil can find its way into the material under treatment. Over the trough is a pyramidal cast-iron cover, which is provided with thumb-screws and packing to secure an air-tight joint. As shown in Fig. 85, it is in position for working, but to operate requires the connections made with the condenser and pump.

Fig. 86 shows a complete plant with the trough A uncovered and tilted for automatic discharge of the batch. This plant is only of small size, but illustrates the essentials of the accessory apparatus to the large size trough shown in Fig. 85. The primary condenser B has a set of tubes surrounded by a cold water current, while in the secondary condenser D ice or a freezing mixture is used. The pump C is of the dry air valve type on stand, and belt driven.

The troughs are made of various standard sizes, from 8 gals. to 550 gals. capacity. It will be seen that the process is a batch one, the given quantity being placed into the trough, the cover lowered by the counterweight, all connections made, and the pump started. Steam being turned on, all proceeds automatically till the batch is uniformly dried to the required consistency, when the cover is raised and the trough tilted to empty. To allow of extra inspection, observation windows are fitted in the cover, and through these any desired additional ingredients may be passed.

CHAPTER IX

EVAPORATIVE DRYING INSTALLATIONS

Drying Kilns.—Characteristics—Hop Kiln—Lime Kiln—Phosphate Kiln—Fuller's Earth Kiln—Barytes—Balloon—Brunton Rotating Bed Kiln—Bietrix Kiln—Leusert Compartment Kiln—Lennox Compartment Kiln - - - - - - - - - 173-179
Drying Stoves.—Characteristics—Hilgrif Core Stove—Louvre Stoves—Piftin Hot Air Stove—Plate or Table Stoves—Riebeck Stove—Gas-fired Enamelling Stove - - - - - - - 179-183
Drying Cylinders.—Characteristics—Construction—Single Cylinder Rotary Dryer—Howell-White—Thomsen's Patent—Lennox Patent—Horizontal—Argall Four-Cylinder—Grill Four-Compartment Dryer—Bruckner—Hockin-Oxland—Ruelle's—Cummer—Middleton-Yeadon—Jones' Patent Batch Cylinder—Distributor Plate—Steam-Heated Cylinder Dryers—Combination—Hersey—Newhall—Sugar Drying Plant—Erith's Coil-Heated—Schultz Multitubular—Drum or Roller Dryers—White's Patent Cylinder—Dyer's and Curtain Frame Cylinder—Hank Yarn Drying Cylinders—Tullis' Patent Roller Dryer—Decoudoun Dryer—Feather Tumbler Dryer - - - - - - - - 183-203

Characteristics.—Kiln is one of the terms used very vaguely for many different types of apparatus, and for a number of different purposes, but is here used only where the products of combustion pass among the material in a building used for drying. A typical case is the old-fashioned *hop kiln*, where the fire was and is built in the ground floor. The heated air and the whole products of combustion passed upwards through the hop floor and hops into the cowl top. This has had many improvements, one of which is illustrated under Drying-rooms, Fig. 128.

A *lime kiln* is a type of the kiln which, as mainly used for causing a chemical change, does not come within the scope of the present book. Many of the kilns used for calcining, roasting, &c., are also used for drying, and have been developed to a high degree of efficiency.

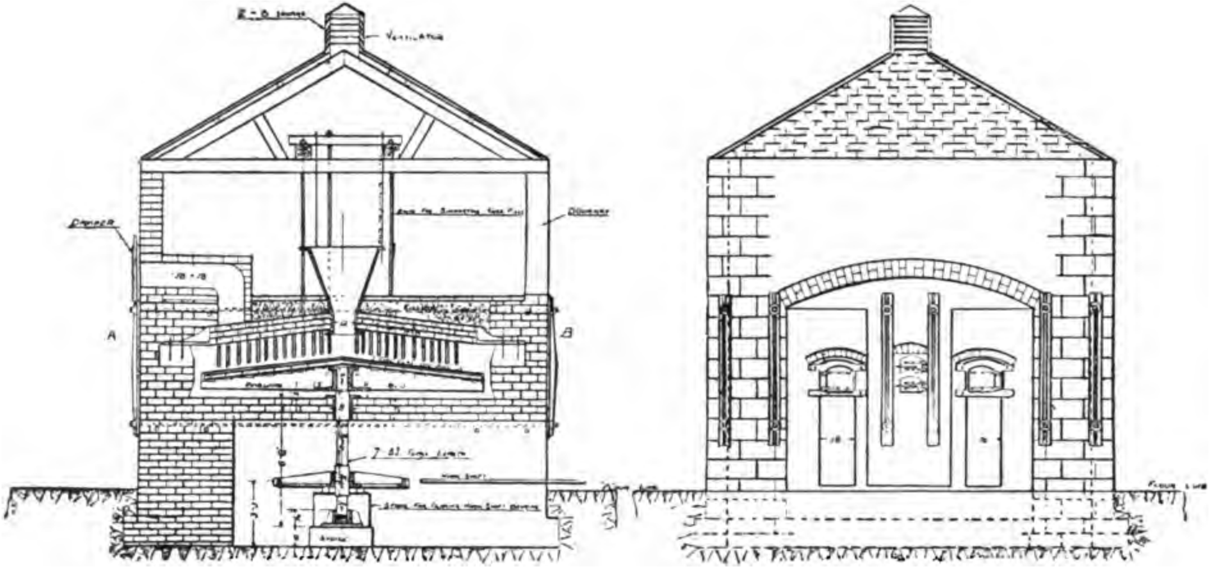
As the direct heat is used, kilns are not suitable where careful graduation of heat or low temperatures are required, while as the products of combustion mingle with the material, the fuel must be suitable, and it debars their use for all substances which are required pure. The saving of heat by the walls of the kilns is in most cases the main consideration, but is often quite counterbalanced by the want of proper exits for the vapour.

In treating *phosphate of lime* a crude *kiln* is made in South Carolina and elsewhere in plain brick rectangular buildings covered with wood roofs. The floor is piled with wood and the phosphate placed upon it. Flues admit air for combustion and circulation. Such a kiln will burn about two to five days, and dry 1,000 to 1,200 tons ready for export. This is doubtless a simple process, entailing a small initial outlay, but the labour is heavy, and unnecessarily objectionable. Still, with cheap labour and a hardy material it deals with large quantities at a low cost.

A usual type of *kiln* for *fuller's earth* and *clays* in chunks is an improvement on the above, in that the heat is more under control, and the ashes do not get mixed with the material. In form it is like a tunnel with partly open top, although sometimes it is built with ordinary vertical walls and timber or slab roof. The furnace is built in a trench of plain bars of iron, and the coal or coke placed on them and fired. The chunks of clay are placed on shelves made of wire meshing or perforated plates. These shelves extend one above another on each side of the kiln, and the top one right across like a false floor. This is an effective dryer, fairly economical of coal, but working by batch. The labour of placing and removing the clay or fuller's earth in the atmosphere of the kiln is laborious, and unnecessarily objectionable.

An improved kiln of this type is used for the purer qualities of fuller's earth suitable for domestic purposes. In this the form is more like a hop kiln, with the furnace, however, much closer to the perforated floor, and with floor tiles of thick fireclay to withstand the heat. This method allows of a more careful watching and partial continuous use. The labour is less and not so objectionable.

In similar kilns to the usual fuller's earth the *cakes of barytes* and of chalk (whiting) are placed as removed from the floors. Some of the kilns have a huge cast-iron globular vessel



SECTIONAL ELEVATION

FIG. 87A.

FRONT ELEVATION

FIG. 87B.

BRUNTON ROTATING BED KILN.
(Wilfley Mining Machinery Co., Ltd.)

in the middle of the kiln, called a *balloon*, to retain the heat and thus increase the efficiency. The cakes are placed on iron racks and usually take twenty-four to forty-eight hours to dry.

Many of the *rotary dryers* described under Cylinders are of the kiln type, and in many cases the makers have called them kilns even where they form no essential part of the building fabric.

A kiln, called *Brunton*, used for drying phosphate of lime, coal for briquettes, and similar materials which require considerable heat but not to be calcined, is quite of a distinct type.

The *Brunton Rotating Bed Dryer*, also extensively used as a roaster and calciner, is only suitable for materials which will allow of close direct firing. Essentially it consists of a rotating iron circular bed on a vertical driving shaft, covered by a fire-brick arch in which are fixed blades to stir the material while drying. The two elevations, Figs. 87A and 87B, show the construction.

The bed is generally about 15 ft. diameter of stout cast iron, and rotates slowly according to the material it carries.

The vertical shaft requires to be of stout steel carried in a substantial footstep bearing, and may be driven either by bevel or worm gearing. The covering arch serves to retain the heat and to support the stationary bars which have iron flukes or blades attached at varying angles to agitate and slowly move outwards the material on the bed, thus automatically discharging it when dry. The feed hopper is central with the bed in the illustration but is sometimes slightly on one side to allow the vertical shaft to project through and get a steady top bearing. There are two fireplaces so situated that their heat and product of combustion all pass over the bed plate before entering the flues.

The temperatures used are generally high, but for suitable material the saving of labour in handling and low first cost, combined with its durability, fuel economy, and drying efficiency, make it a popular form of kiln for ores and coal for briquetting. In France a practically similar design is called the *Bictrix Kiln*.

Although the wear and tear are naturally low, the coal combustion small, and the heating very efficient, as the temperatures range from 212° to 392° Fahr., the continual stirring of the material gives good vaporisation. In those used for

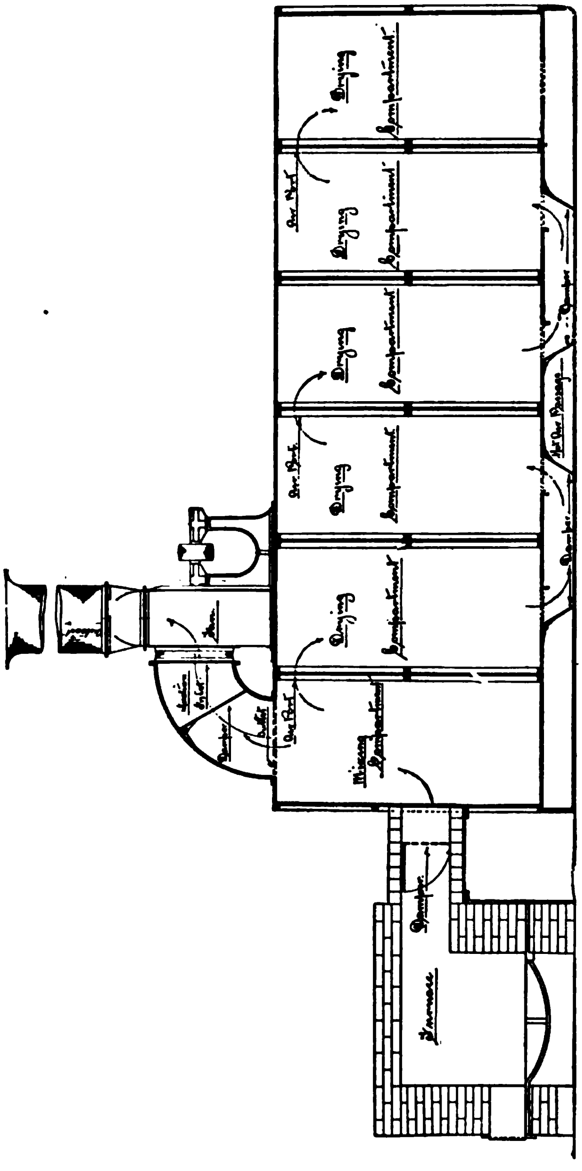


FIG. 88.—CELLULAR COMPARTMENT KILN. SECTIONAL ELEVATION.
(A. B. Lennox.)

briquetting coal the pitch is sometimes mixed with the coal, and the two dried and mixed in this kiln quite satisfactorily as they leave at about 176° to 203° Fahr.

A kiln which may also be used as an effective drying oven is the *Leusert Compartment Kiln.* This forms a building 24 ft. high divided by walls into compartments. These compartments contain a number of flat vertical metallic tubes which have inside metal louvres down which the wet material gradually gravitates, while being dried by a well-regulated transverse current of hot gases from the furnace.

The *Lennox Compartment Kiln* is a built-up nest of drying cells or rooms, but as using not only the heat but allowing the product of combustion to pass through them, it becomes a true kiln. As will be seen from Fig. 88, the sectional elevation, and Fig. 89, the ground plan, the furnace and the dryer cells all work on induced draught or the exhaust process. The heat is generated in a brick furnace outside of the dryer and having two alternately used flues. The two flues enable the air currents to be reversed in direction by opening or closing the respective dampers.

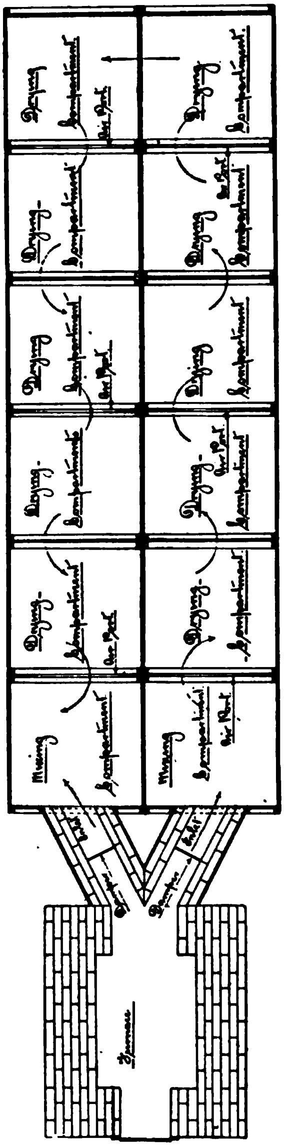


FIG. 89.—CELLULAR COMPARTMENT KILN. PLAN, PART IN SECTION. (A. B. Lennox.)

The heated air current on leaving the flue proper passes into a mixing chamber to be diluted to the required degree with cold air to suit the particular material.

This prepared air current passes into the top of the first drying cell through the material and out at the foot of the first cell into the second cell. The air current then passes through the material of the second cell into the top of the third cell. In the third cell it repeats the course of the first cell, and so on in each odd cell. In the fourth cell it repeats the course of the second cell, and so on in each even cell till it reaches the last cell where the suction fan withdraws the vitiated air and expels it. For material remaining stationary during the process, this kiln offers thorough aeration and economical drying as to fuel consumption. The placing of the material would vary with its size and character, hence is not shown. Its compactness and simplicity are striking features, while the alternating of the air currents ensures an even sample with regular drying.

Drying Stoves.

Characteristics.—As generally used, "stoves" is a term having a very wide application, but as related to drying it is best restricted to those dryers which, while containing a combustion chamber or furnace similar to a kiln, yet do not form a building or an essential part of the fabric in another building. Using direct firing and allowing the fumes to mingle with the material they have the same restricted scope as kilns. Their initial cost is usually less, the convenience of removal greater.

A typical compact, self-contained stove called the Hilgrif Core Stove is shown in Fig. 90. Here is clearly seen the furnace attached to the drying oven. For drying cores in iron, steel, and brass foundries it is very convenient and economical. The shelves hinge in a manner to prevent loss of heat and practically no space is wasted. In the small space of 6 x 4 x 2 ft. it offers five shelves for *core drying*, which can be filled or emptied independently.

A compact stove in which no power is required consists of a series of *inclined shelves* or *louvres*, down which the material gradually gravitates while exposed to the direct heat of the hot gases from a fire below, or the flue gases from a kiln used for roasting. This is well suited for materials which will gravitate, *e.g.*, iron ore, limestone, sand, quartz. Edison has designed a stove of similar type, which has gear for tilting the shelves to assist the gradual fall (see also Fig. 155).

A compact apparatus which forms a complete portable drying stove is the *Piftin Hot Air Stove* (Fig. 91). It consists of a closed box with a fire-resisting lining charged with 25 lb. of coke. This box has a 4-in. inlet for an air blast from an ordinary fan, and a 4-in. outlet at the bottom for the hot air. The hooks shown are merely for convenience of lifting. The coke lighted and the blast started, the stove can be left without attention on the top of a moulding box for hours, when it can be recharged with 10 to 18 lb. of fresh coke, and again left to dry the mould. Its effects are approximately those of about six "devils," usually doing such work and requiring about 75 lb. of coke each. The temperatures obtaining for this mould

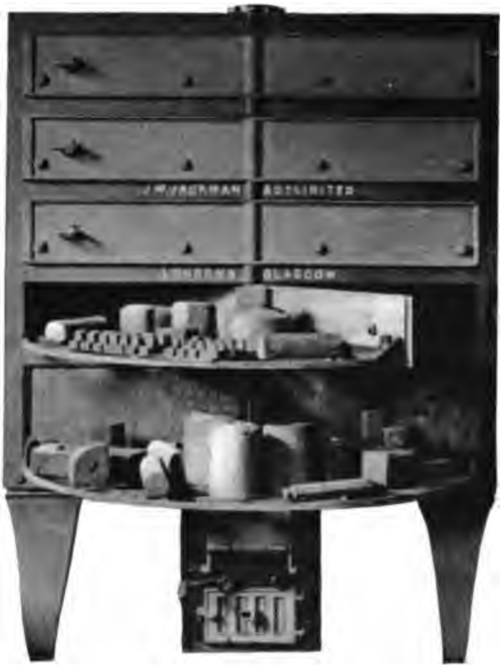


FIG. 90.—HILGRIF CORE STOVE.
(J. W. Jackman & Co., Ltd.)

drying are 450° to 500° Fahr., and this can be imparted to 10,000 cub. ft. of air with 25 lb. of coke. A corresponding amount of heat can be supplied at a higher temperature when required.

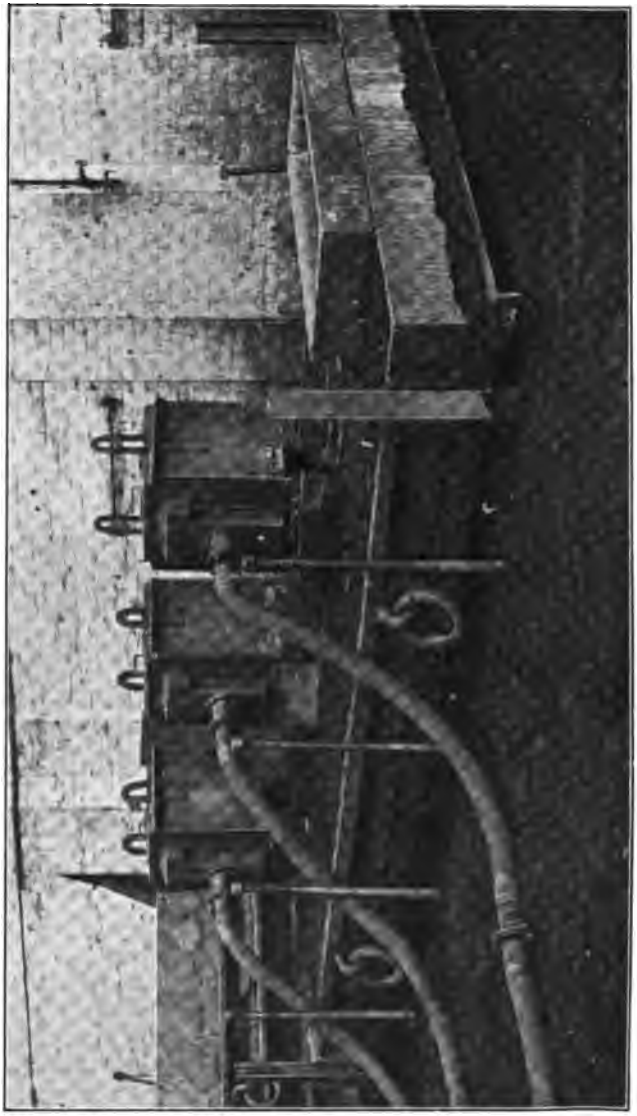


FIG. 91.—PORTABLE HOT AIR MOULD DRYER (PATENT). THREE IN OPERATION. (Pitkin, Ltd.)

A type of *plate stove* dryer which is sometimes built in by brickwork so substantially as to become a real kiln is the *Kiebeck.* Essentially it consists of a number of stationary *plate-like circular shelves,* or tables about 12 ft. diameter. They are supported above each and about one foot apart by eight columns round the circumference and surrounded by plate steel casing or brickwork. Through the centre of these fourteen or so tables passes a vertical revolving shaft which carries arms having knives or stirrers attached. The material is fed by a hopper on to the top plate, the knives gradually move it over a central hole when it drops on to the second plate. The knives above the second plate gradually move it over a similar hole on the periphery of the second plate whence it drops to the third plate. In this manner it passes automatically

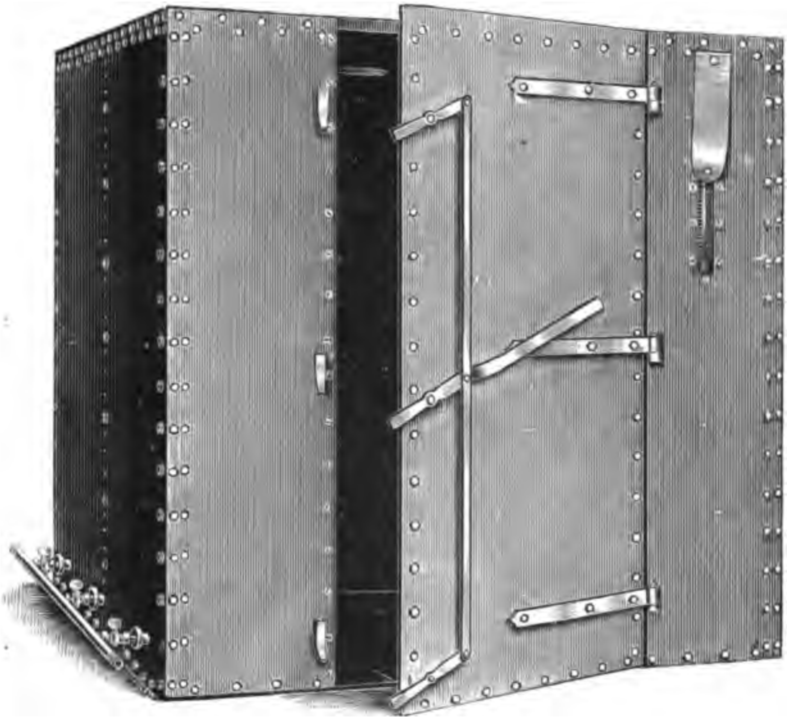


FIG. 92.—GAS ENAMELLING STOVE.
(Jones & Attwood, Ltd.)

from plate to plate till it is discharged at the bottom, having been thoroughly heated and dried by the hot gases from a fire at the bottom on one side. As an automatic feeding and delivering stove it has great advantages, but the direct firing limits its application although economical of the fuel. A powerful exhaust fan is essential to good working in this and the similar dryers heated by steam and hot air pipes described under Ovens. With the direct firing they are useful for earthy brown coal and similar material, but need careful regulation as to firing, especially as the heat is greatest where the material is driest.

The *Gas Enamelling Stove* illustrated in Fig. 92 by a general view, while primarily designed for drying enamelled or lacquered goods, is in a form to accommodate other drying by direct gas heat. The stove is built up of steel channel frames covered with steel plates inside and outside. Between the two casings is packed with silicate cotton. This insulation is extended to the door also, thus economising heat. The heating is by a series of gas jets on the Bunsen burner principle. The vapour removal is shown at the top but may be modified to suit material. The internal arrangements are, of course, dependent on the particular purpose for which it is being used. This is a convenient economical type for heating by steam, hot water, or hot air, in which case it comes under the classification of drying-room.

Drying Cylinders.

Characteristics.—Under the term of cylinders it is intended only to embrace those dryers in which the portion of the apparatus retaining the material is essentially cylindrical (or truncated cones) in order to allow of a rotary motion. The fact of a portion of a dryer being cylindrical or conical is not the distinguishing feature, but the shape as a means of facilitating the motion. As some are direct fired, some have hot gases and steam passed through, while others have steam jackets and steam pipes. They offer quite a wide range of types, and a still wider range of capabilities for degrees of drying, roasting, and calcining.

For any material which is not injured by constant and violent agitation, they offer many advantages and economies.

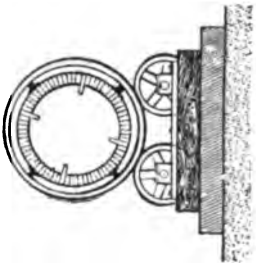


FIG. 94.—TRANSVERSE SECTION.

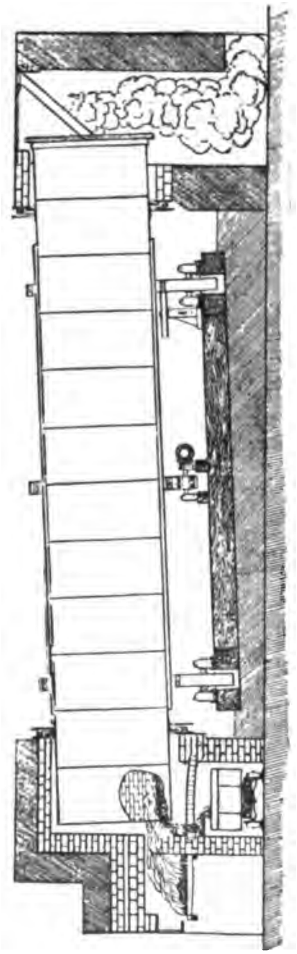


FIG. 93.—LONGITUDINAL SECTION.

HOWELL-WHITE CYLINDER DRYER.

(Wilfley Mining Machinery Co., Ltd.)

In their various forms they can deal with any degree of fluidity, and reduce to absolute dryness or desiccation. Given suitable material and the necessary power, cylinders will give large automatic delivery of a uniformly dried product with minimum attention and great economy of fuel.

Construction.—A typical cylinder dryer is shown by Fig. 93, in longitudinal elevation and part section, and Fig. 94 in transverse section. The essential features are (1) a revolving cylinder rolling on (2) the rollers, and (3) shaft to carry the gearing, (4) a furnace, (5) the hopper feed, (6) the shoot delivery, (7) a flue to create a draft and carry away the products of combustion and the vapour.

The cylinder is shown as built up of steel plates with stout ring outside to form roller path and to form gear. It has a thick renewable fire-brick lining (this is not needed for drying), with projections to lift the materials. It is inclined at about 1 ft. in 12 ft. to the horizontal, is about seven times as long as its diameter, and should revolve about three times per minute. Each end

is shielded by brickwork to prevent heat losses and allow for expansion. The rollers are of cast iron on steel gudgeons in pairs at each end.

The driving shaft is a short independent one with spur wheel gearing into the spur ring on the cylinder, and a bevel drive from the main shaft.

The furnace is of the ordinary bar type to be hand stoked, built in brick, and overlaid with non-conductor of sand.

The feed is a steel plate or cast-iron hoppered shoot from the top of the flue chamber into the cool end of the cylinder.

The delivery is a cast-iron shoot from the hot end of the cylinder through an arched tunnel for the receiving trucks.

The flue is here shown with brickwork to cause down draft, and may lead to chimney or fan chamber.

Fig. 95 shows a general view of a very similar dryer and gives a fair idea of the massive build of these machines. The drive in this case is by longer shaft and spur reduction gear. The furnace and flue are well stayed and strengthened, and the whole is made as a self-contained machine. These are samples of direct positive firing with all the products of combustion passing directly into and among the material. They are intended for even the highest temperatures as calciners as well as dryers, and are in use for both purposes practically all over the world, often going under the name of *Howell-White Calciner.*

Thomsen's (Patent) Rotary Dryer, while essentially the same kind of machine, is designed on very different lines, as will be seen from the sectional longitudinal elevation, Fig. 96, and the end view, Fig. 97, together with the transverse elevation, Fig. 98.

The cylinder is of steel plate, but needs no roller path, as it is carried on stout gudgeons at each end, and these run in roller bearings outside, away from all heat. There is no ring gearing, as the drive is by spur gear on to the gudgeon at the feed end. No fire-brick liners are shown, as none are needed, and into the cylinder casing are fitted a series of external hooded openings which alone allow the hot gases to enter the cylinder, though they prevent the material from rolling out. The whole cylinder is heated externally, and is encased entirely by brickwork to ensure the heat storage. By this arrangement the heat is

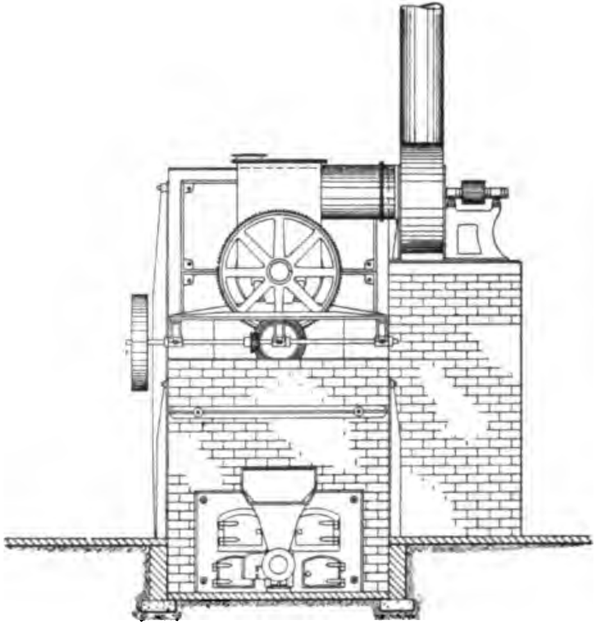


FIG. 97.—FRONT ELEVATION.

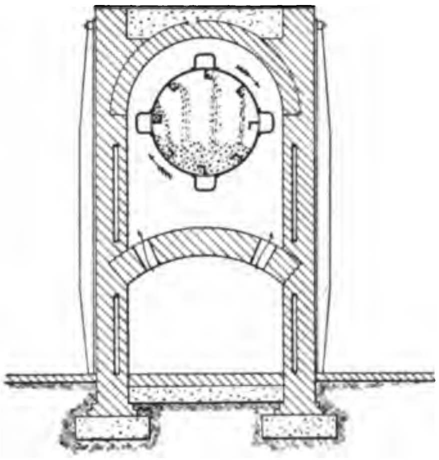


FIG. 98.—CROSS SECTION.

THOMSEN'S (PATENT) ROTARY CYLINDER DRYER.
(Erith's Engineering Co., Ltd.)

introduced in a more gradual and systematic manner, while no intense heat comes in contact with the material.

The rollers and roller paths are replaced by the gudgeons and their special swivelled roller bearing. The shaft for the gearing is on the gudgeon at the feed end, and countershaft below.

The furnace is also quite different, there being an under-feed stoker to use bituminous slack, although any fuel can be used with this type of dryer. With any fuel, however, it will be noticed that in addition to the furnace proper there is here a built-up double bridged expansion chamber in addition to the chamber in which the cylinder revolves. This expansion chamber forms a collecting place for all the dust or other objectionable parts of the products of combustion. It also serves as a reservoir of heat to allow the whole capacity to be used in such quantities and at such temperatures as may be desirable for the particular material, thus obtaining the full benefits of complete combustion and complete adjustment of supply.

The feed hopper acts as a hood to the top end of the cylinder and also as the flue outlet, but is at the same end as the firing.

The delivery has a shut-off valve and is at the opposite end to the fire and flue.

The flue is merely a sheet steel chimney, but adjusted and regulated by an exhaust fan, thus obtaining the economies and careful regulation only obtainable by mechanical draught.

The *Lennox Horizontal Rotary Dryer* presents a self-contained machine of this type without any necessary brick building or heavy foundations, and has features distinct from those previously described (see Fig. 99).

The cylinder is of steel plate but not inclined and entirely encased by an outer stationary cover of plate steel. The roller paths are lighter and at the ends. Inside the cylinder is an arrangement of inclined plates on which as the material falls it is gradually transmitted to the delivery outlet. There is no lining shown or required for drying purposes.

The cylinder being horizontal and light the rollers only require to be of light build and the power absorbed is very small. The drive is by wheel on the cylinder and worm with plain belt pulley fixed on the delivery end.

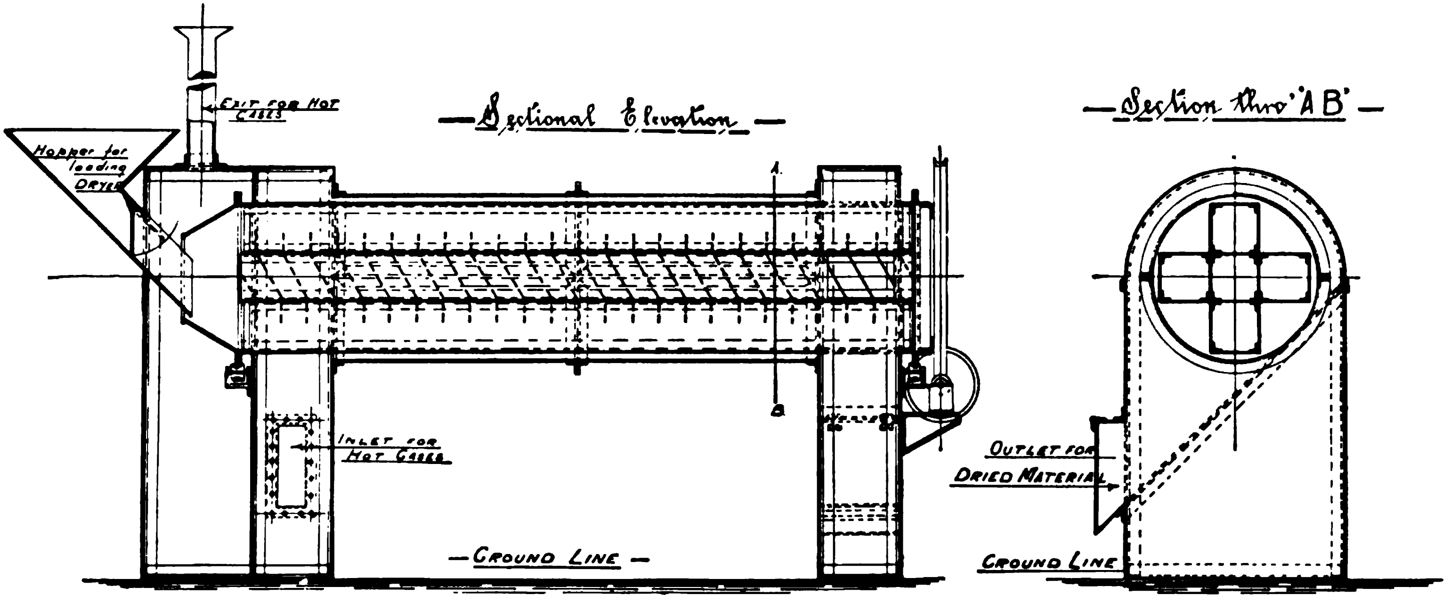


FIG. 99.—LENNOX HORIZONTAL ROTARY DRYER (PATENT).
(A. B. Lennox.)

No furnace is shown, as it is designed to use surplus hot gases from a kiln, retort, or ordinary furnace; if wanted to work with independent heat it could readily have any kind of furnace attached. The hot gases are conducted along the outside of the whole length of the cylinder and then along the whole length inside into a steel plate flue.

The feed is by steel plate hopper with regulating valve into the tapered end of the cylinder. The delivery is by shoot in the tail end support through holes cut in the cylinder.

The *Argall type of Rotary Dryer* is a development of the plain cylinder in the direction of ensuring more intimate contact of the hot gases with the material by introducing four smaller cylinders inside the main rotating cylinder.

As shown in Fig. 100, all portions of the cylinders, main and primary, are shielded by a coating of fire-brick and ganister, but for drying purposes these are not necessary, otherwise the dryer is built as drawn.

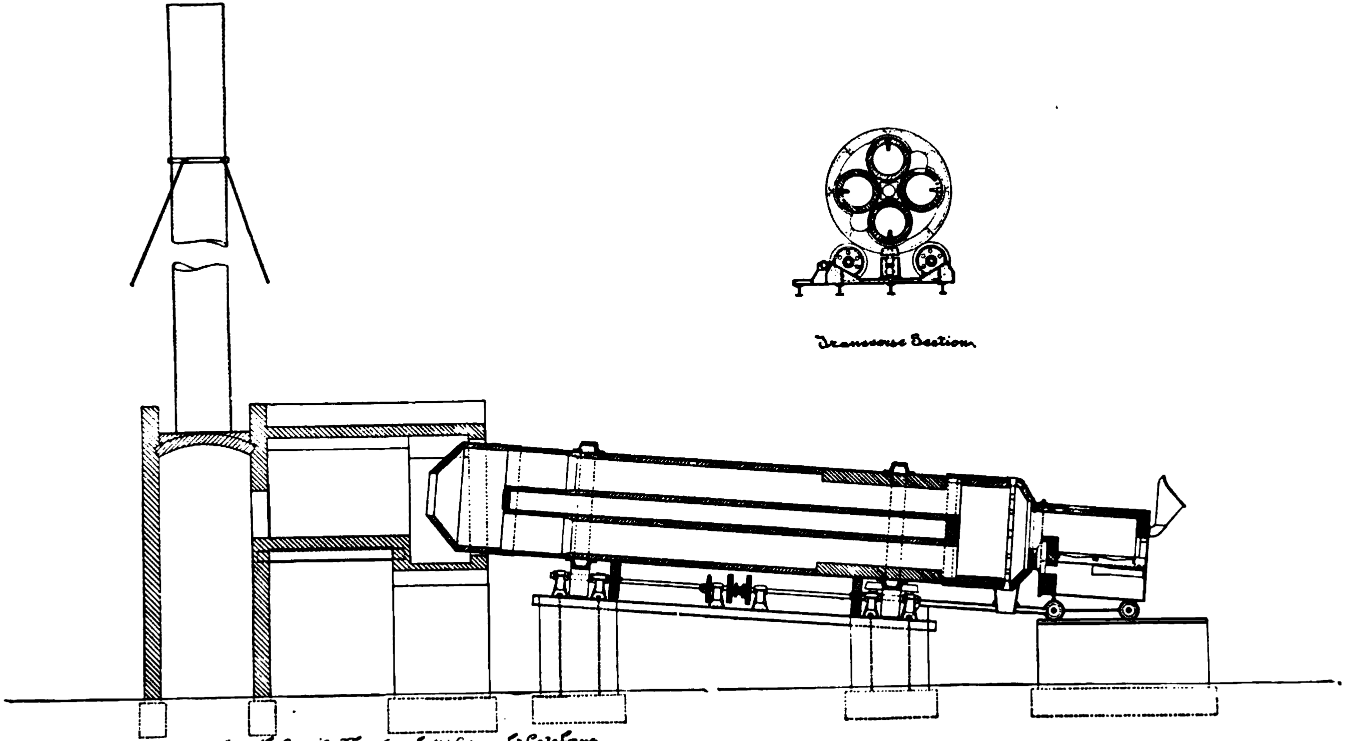
The main cylinder is of plate steel with stiffening and roller rings similar to Figs. 93 and 94. The receiving end is tapered to retain the feed. The four inner cylinders are somewhat shorter than the main cylinder and are held in position by sectional removable frames. The material falls into each of the inner cylinders in turn, and the rotation together with the inclination causes it to be transmitted and delivered through the slits shown in the outer cylinder.

The drive is a frictional one, as the cylinder is weighty, while the reduction in speed is by the spur gearing.

The furnace is in a detached but stationary casing on four trolley wheels to allow for expansion and contraction under the great heats. There is an automatic feed hopper and self-cleaning bars attached to the furnace casing.

The feed is at the cool end by hopper and shoot through the flue chamber. The delivery is into an adjustable hopper through the slots in the cylinder. The vent is into a chamber and then by the chimney shown as a steel plate one, and having ample convenience for depositing any fine dust or sublimed minerals.

The *Grill Four-compartment Dryer* assumes the cylindrical form, but is divided into four equal compartments with diagonal air passages between them.



from The Cyanide Plant Supply Co's Copyright Catalogue

FIG. 100.—ARGALL ROTARY CYLINDER DRYER. SECTIONAL ELEVATION.
(The Cyanide Plant Supply Co., Ltd.)

Each of the cylinder dryers described above is adaptable for use with high or moderate temperatures in dealing with materials which need them and allow of the agitation. For instance, chalk, marl, limestone, or clay at cement works, brick, tile, or pottery works; for shale, sand, crushed quartz, phosphates, and many kinds of ores and minerals.

For superphosphates, fish, bones, and other manures, the feed is generally at the firing end of the cylinder in order to have the greatest heat while the material is wet and to prevent charring the dry powder. A well-designed machine of this type will receive large fish direct from the water, and by drying and agitating will deliver them at the outlet as a dry mealy powder containing less than 10 per cent. moisture, and free from smell.

The *Bruckner Dryer* while mostly used for roasting is adaptable for drying. Essentially it is a batch working cylinder revolving on the usual rollers but higher from the ground to allow trucks under when discharging. The cylinder is tapered at each end, the furnace, being stationary except for expansion, has its direct connection with the one end and the flue leaves at the other end. The feed is from storage bins through a manhole in the periphery of the cylinder and the discharge is by the same manhole when reversed. It is intended for high temperatures and large loads, for instance, a 6 ft. diameter by 12 ft. long cylinder will carry 3 to 4 tons, while an 8 ft. 6 in. diameter by 22 ft. long will carry 10 to 15 tons.

There are a number of variations of these direct fired dryers known under the names of their designers or makers, and all having some special advantage for their original purpose. Among these the *Hockin & Oxland Dryer* or *Calciner* has an inclined screw feed and longitudinal ribs of fire-brick or iron extending two-thirds of the length of the cylinder. *Ruelle's Dryer* has an inner truncated cone along which the material is dried and transmitted by spiral blades attached to the sides of the cone. When the material reaches the fire end it drops through some slots into an outer shell which has also attached spiral blades to convey the material back and during transit allow it to cool down. In the *Cummer Cylinder Dryer* the hot gases from the furnace are drawn by an exhaust fan around the inclined cylinder, and afterwards through it. Internal longitudinal blades lift the material and allow it to fall through the hot gases. *Middleton & Yeadon's Cylinder Dryer* has a double furnace under the central portion of the cylinder, and the hot gases are conducted round the cylinder by a casing with a double or alternate outlet. Thus the gases may be led away into the flue direct or back into the cylinder from the delivery end, and thence down near the feed end into a secondary flue.

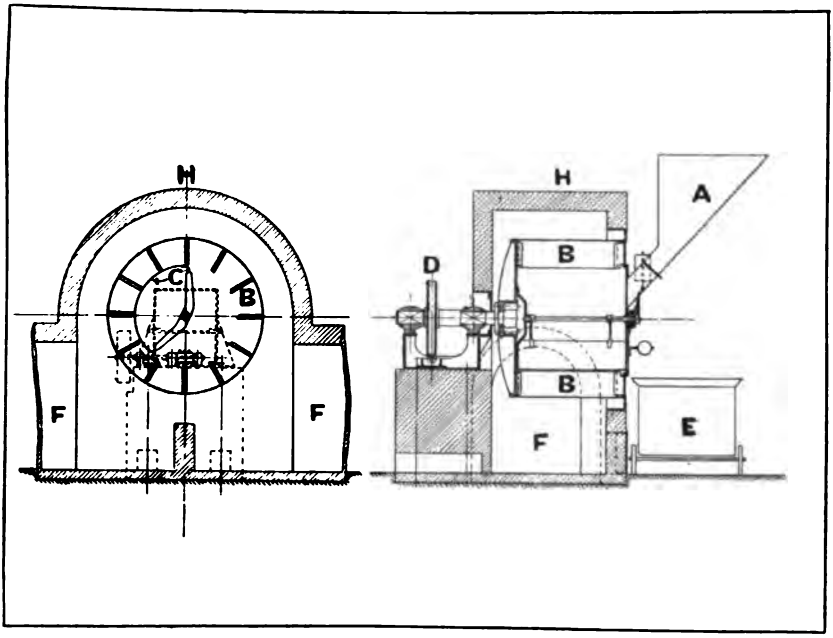


FIG. 101.—JONES' (PATENT) CYLINDER DRYER. SECTIONAL ELEVATIONS. (L. Jones.)

The cylinder is horizontal and has six spiral blades attached to the inside for lifting and transmitting the material.

All the cylinder dryers so far described are automatic in their feed and delivery, and continuous in their action. Hence they require their transporting gear to accord with their cylinder length and their drying capacity. Otherwise the material will be delivered before properly dried, or retained beyond the time necessary. It follows that if the wet material differs considerably in its wetness when of the same kind, it will not produce an equally dried sample as finished product. If the nature of the wet materials is different, an even greater variation may arise. Thus to accommodate a variety of materials, the cylinder should be adjustable. With megass and similar vegetable products, however, the same consignment may vary considerably, and this indicates the advantage of a batch working. In Fig. 101 is an illustration of a batch working cylinder dryer, the most striking features of which are its compactness and the distributor plate marked C. This distributor plate retains the wet material in the sections and against the cylinder much longer than is usual in cylinder dryers. This secures longer contact and more thorough cascading of the material as it falls back over the *distributor plate.*

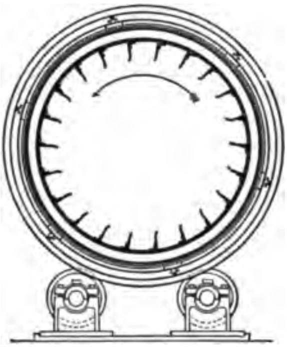


FIG. 102.—NEWHALL ROTARY CYLINDER DRYER. VERTICAL SECTION.
(Manlove, Alliott, & Co., Ltd.)

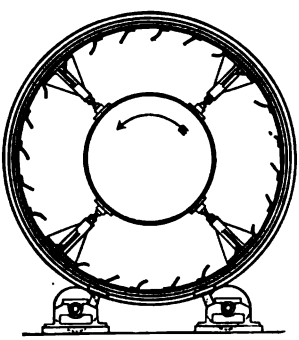


FIG. 103.—HERSEY ROTARY CYLINDER DRYER. VERTICAL SECTION.
(Manlove, Alliott, & Co., Ltd.)

When the megass or other material is dry, the distributor plate can be swivelled round to cover over the bottom sections of the cylinder interior, and thus as the cylinder revolves it will discharge its entire load on to the distributor plate ready for raking out. In other respects the *Jones Cylinder Dryer* is of a typical belt-driven type. Reduction of speed is by cross spur gear D. The interior of the cylinder is divided into sections at the periphery by plates B, against which the distributor plate C retains the material. A shows the hopper and shoot for feed, E the discharge truck and F F the furnace and flues, H the arched-over brickwork for heat economy. The hot gases do not enter the cylinder, and all the drying is by the heat conducted through the plates of the cylinder.

Steam Heated Cylinders.—The cylinder dryers are very adaptable for heating by steam and thus meeting the requirements of other materials, such as sugar, soda, salt, filter pressed distillers' grains, filter pressed waste from starch works and slaughter-houses, cocoa, coffee, and other berries and crystalline substances. They should, however, not be over wet, say 25 to 30 per cent. moisture. Steam cylinders can be arranged to deal with the more wet materials, but other types are more generally economical, for instance pans.

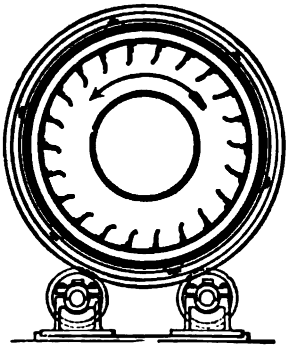


FIG. 104.—COMBINATION ROTARY CYLINDER DRYER. VERTICAL SECTION. (Manlove, Alliott, & Co., Ltd.)

The *Combination Rotary Dryer* shown in Fig. 105 gives a general perspective of a typical steam cylinder dryer, the essentials being (1) the cylinder, (2) the roller and paths, (3) the driving gear, (4) the steam heating gear. The sectional Figs. 102, 103, and 104 show in cross section the relative position of the steam gear to the cylinder, while the general arrangement (Fig. 106) shows how the machine is erected in connection with other tackle for sugar granulating.

The cylinder in each case is of steel plate and has on its inner surface a series of shelves or blades, which, besides lifting, also help to transmit and agitate the material. In the "Newhall" type (Fig. 102) the cylinder has a steam jacket over its entire length, while in the "Hersey" (Fig. 103) there is an inner suspended steam cylinder, and the two are united in the "Combination" (Fig. 104). These jackets or cylinders are in each case connected by exhaust or live steam supply and with a steam trap at the outlet.

The rollers and roller paths are similar to those of the direct fired, but are here shown having a swivelling adjustment to allow for any wear in themselves or the gear drive, which is of the spur gear under-driven type.

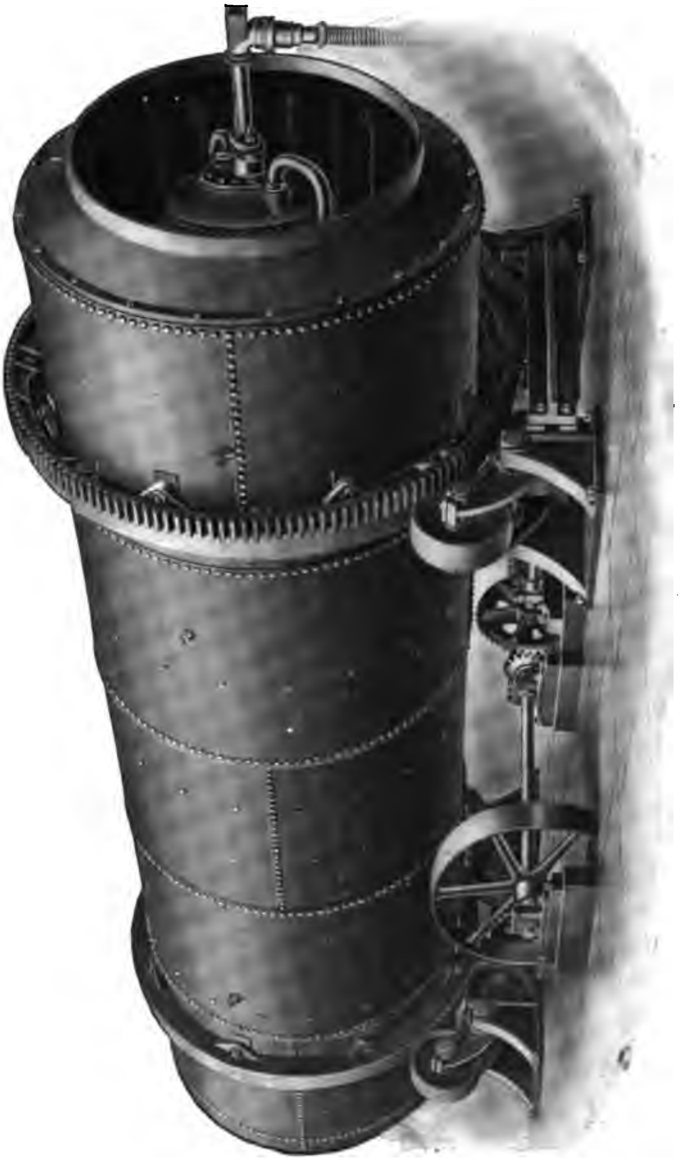


FIG. 105.—COMBINATION ROTARY CYLINDER DRYER. GENERAL VIEW.
(Manlove, Alliott, & Co., Ltd.

The exhaust is taken by fan from the feed end of the cylinder to ensure the saving of all fumes, but as a further precaution it may pass into a stive room previous to being discharged into the open. This design allows of a careful adjustment to the most delicate materials, as the principle is quantity of warm air not intensity of heat. The arrangement for erecting (Fig. 106) shows the delivery of the moist sugar through the feed shoot A and the automatic screw feed B into the cylinder dryer C (Fig. 105). After treatment the sugar passes through the shoot D, to be more completely dried and aerated in the conveyor dryer F (Fig. 84). Passing by the shoot H into the hexagonal revolving screen J, it is separated into three grades of fineness, each grade passing by its own hoppered shoot K into a barrel L, which is automatically packed by the mechanical packers M. As the cylinder C is exhausted by the fan E, and the conveyor dryer F aerated by the blower G, this forms a self-contained automatic drying, granulating, sifting, and packing plant for three classes of product from the one wet sample.

The *Erith Tubular Dryer* shown in Fig. 107 shows a type of steam-heated cylinder in which the inner cylinder is supplemented by a coil of steam pipes. This coil heats the incoming air before it mixes with the grain or other wet material, and by means of the propeller shown at the feed end a copious supply of air is kept in continuous circulation. A machine with a 23 ft. by 5 ft. cylinder has thus a drying capacity equal to evaporating 800 lb. of moisture per hour from wet grain. It is very compact, requires small power, and has automatic feed and delivery.

Among other noteworthy steam cylinder dryers is the *Schultz*, in which the main cylinder, about 8 ft. diameter, contains an inner steam cylinder or drum, which is perforated, thus allowing the steam to entirely surround about 180 pipes of 4 in. diameter, held in two end plates, similar to a tubular boiler. Through these tubes the material passes with an induced current of air. Naturally the material must be of suitable size, also the feeding automatic and carefully regulated.

Drum or Roller Dryers.—There is another class of drying machine usually called cylinder dryers, which would be more

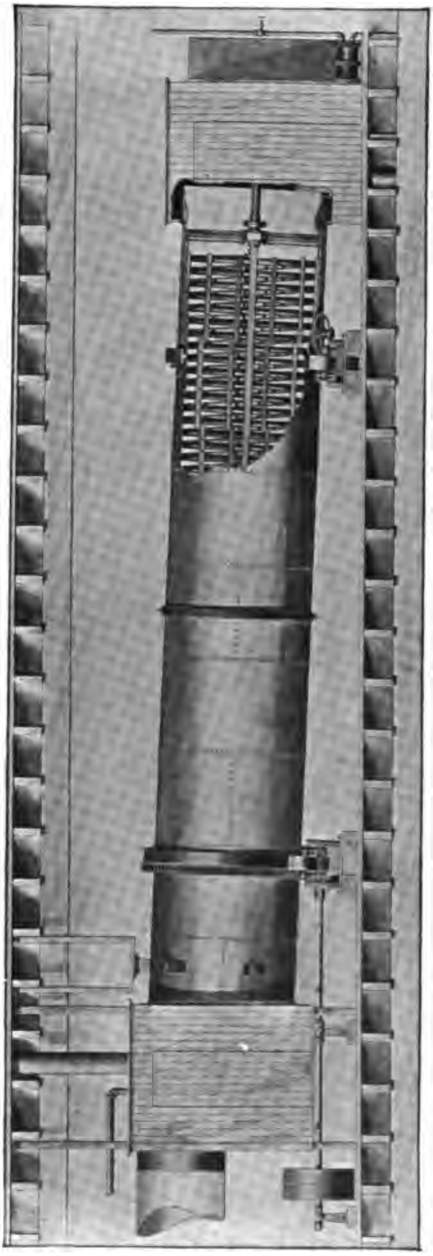


FIG. 107.—STEAM COIL CYLINDER DRYER.
(Erith's Engineering Co., Ltd.)

appropriately called drum or roller dryers. These machines have one or more cylinders (or drums), which are heated, and the material is brought in contact with the outside periphery to be heated and dried. They are largely used in the paper and textile trades.

The cylinders are various lengths and diameters, made of steel, cast iron, copper, or tinned iron, according to the purpose. The steam or hot air for heating enters by the trunnions from a joint supply or individual connections. The cylinder ends vary according to the maker, but Fig. 108, while illustrating *White's Patent Cylinder*, gives the essential features of a typical cylinder, the invention being the method of attaching the ends to the cylinder body. The cylinder body C is bored out, so that the diameter at K is slightly greater than the cylinder end at I, while both are tapered, and the joint made good by the rust-metal ring B. The risk of leakage is still further prevented by the form assumed at A and at E. The usual formation is by screws or bolts through the end into the cylinder body.

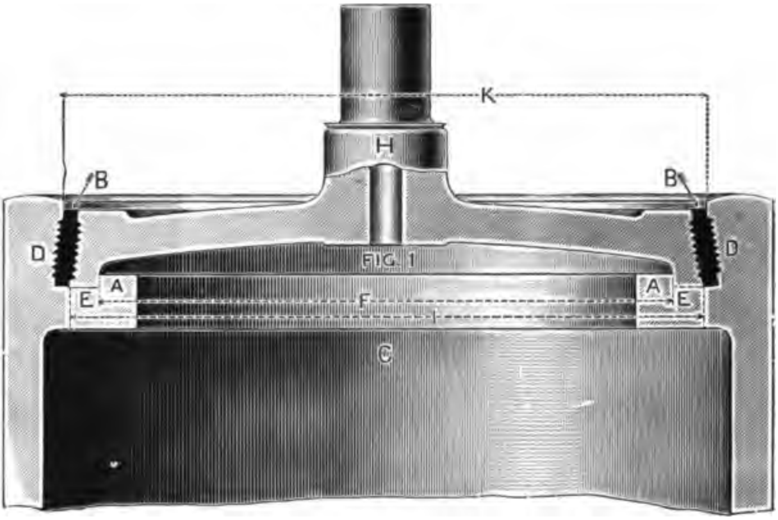


FIG. 108.—WHITE'S (PATENT) CYLINDER. SECTION.

(Jas. Bertram & Son, Ltd.)

In the manufacture of paper the one machine deals with the "half stuff," and after spreading and draining off the surplus water, passes it over one or more such rollers. If both sides are required alike, then each is brought into contact with the heated rollers, the heat being regulated according to the finish required on the surface, and in this case the rollers are small in diameter, but numerous. But where the one face only has to be surfaced smooth, one large roller is used, and all drying is effected from the rough side by heat applied at the smooth side.

Fig. 109 illustrates the form such cylinders assume when used by dyers for drying curtains and other lengthy articles. It also shows the usual method of attaching the cylinder ends, while the manhole and ring for rotating by hand can be clearly seen.

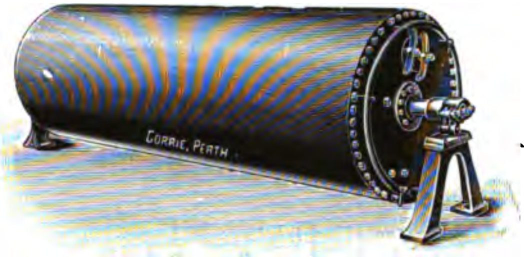


FIG. 109.—DYER'S AND CURTAIN FRAMING CYLINDER.

(D. Gorrie & Son.)

The *Hank Yarn Drying Machine* (Fig. 110) gives an instance of a multiple roller machine as used in the textile trades, particularly for the drying of linen yarn in hanks. The rollers (or cylinders) are all worked in unison, being supplied by steam through the tubular framework at one side of the machine. At the opposite end of the cylinders the condensed water is lifted out by internal buckets, and escapes through their nozzles to the hollow framing, from the lowest point of which it is discharged through a steam trap. The transporting of the material by means of the driven cylinders and wooden skeleton rollers, and the brass coupling links used to connect the several hanks into continuous bands, are well worth notice.

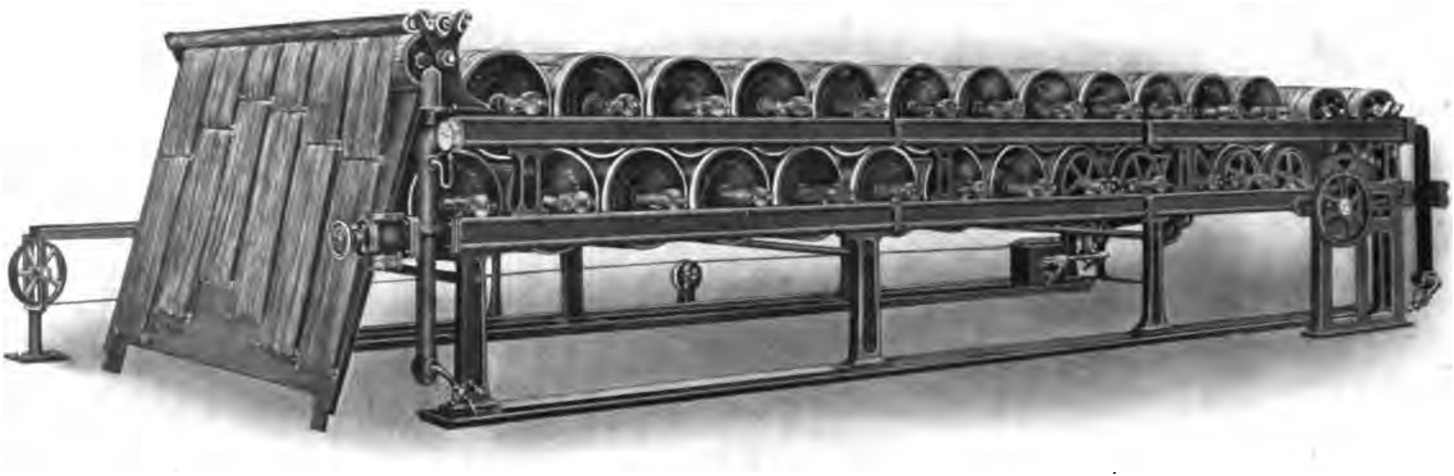


FIG. 110.—HANK YARN DRYING MACHINE.

(Mather & Platt, Ltd.

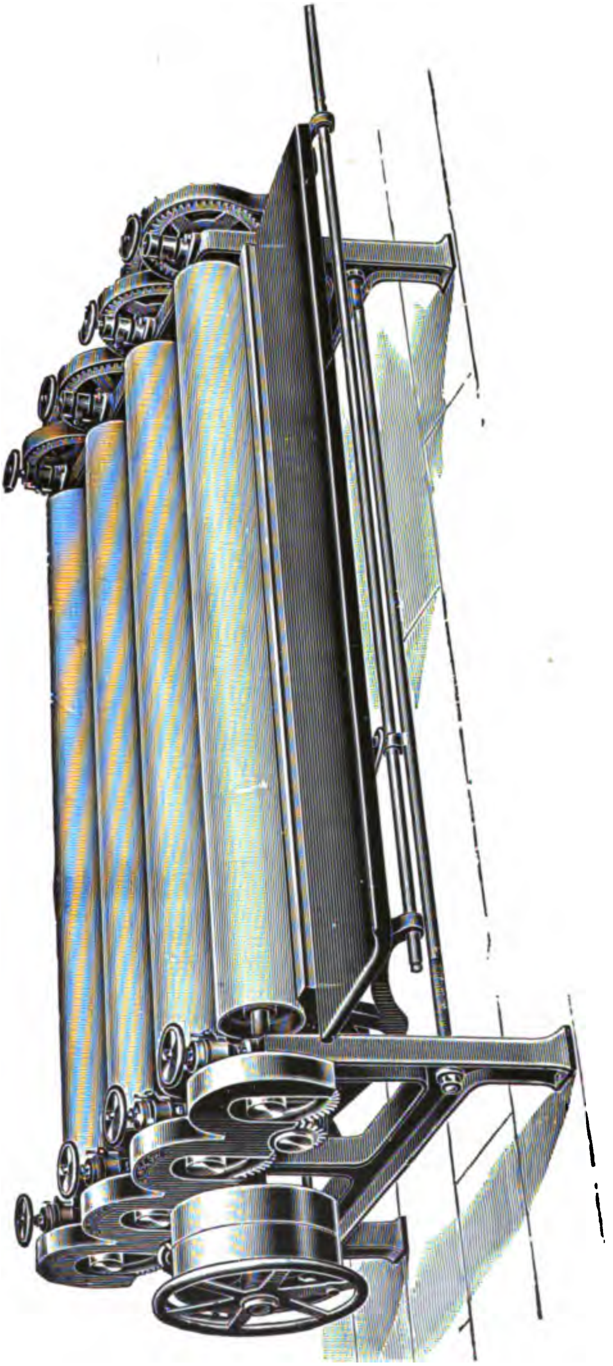


FIG. 111.—FOUR ROLLER DRYING MACHINE (PATENT). GENERAL VIEW.

(D. & J. Tullis, Ltd.)

These skeleton rollers also serve for cooling down the yarn before discharge. This type of machine, with suitable modifications, can also be used for drying warp yarns and piece goods.

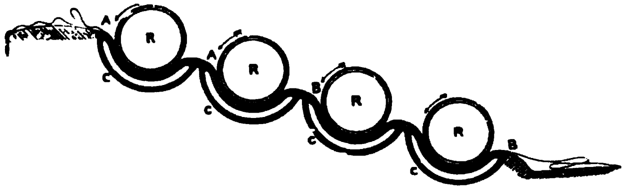


FIG. 112.—FOUR ROLLER DRYING MACHINE (PATENT). SECTION OF BED. (D. & J. Tullis, Ltd.)

Tullis' Patent Roller Drying Machine (Fig. 111) is another form of cylinder or roller dryer. In this case the rollers R are open at the ends, while their peripheries are padded with felt. The heat is applied in the bed C, which is of cast iron, polished on the top face, and having separate steam chests, as shown in the section, Fig. 112. The goods are fed in at the top A, and pass automatically through to the bottom B. The spaces between the rollers allow the vapour and impurities to escape and thus hasten drying, besides keeping the pads on the rollers in better

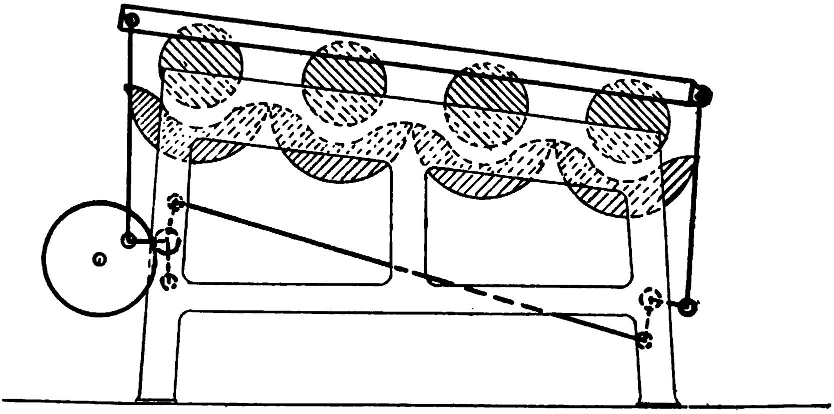


FIG. 113.—FOUR ROLLER DRYING MACHINE (PATENT). ROLL-LIFTING GEAR. (D. & J. Tullis, Ltd.)

PLATE XI.—DRYING MACHINERY AND PRACTICE

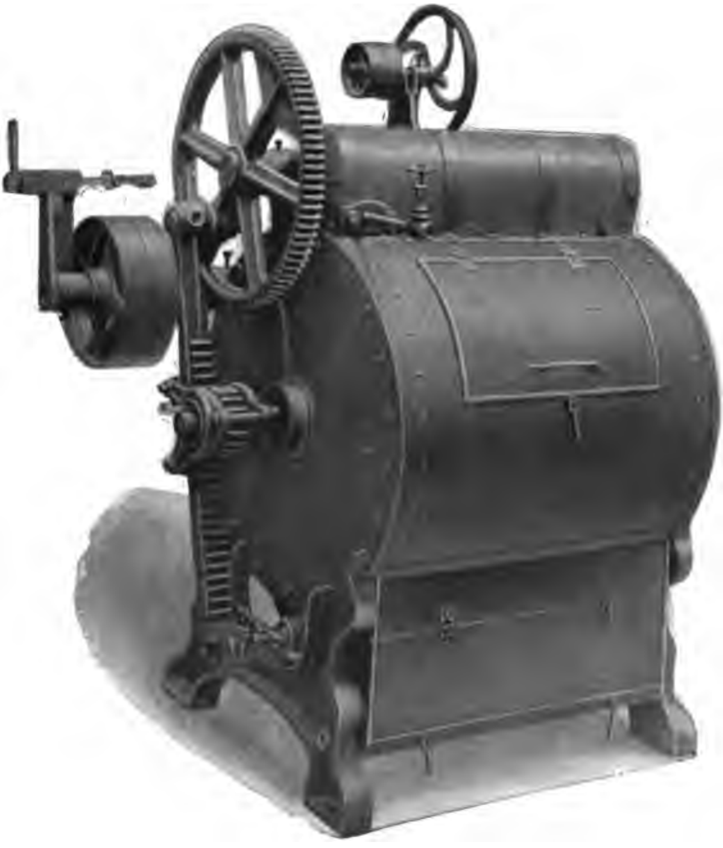


FIG. 114.—DRYING TUMBLER FOR FEATHER FINISHING.
D. Gorrie & Son.)

[*To face page* 203.

condition. The drive is by one belt through gearing at both ends of each roller to maintain uniformity of transit. The speed can be varied readily to suit the goods and the temperatures used. The rollers can be lifted from the bed in battery by the gear shown in Fig. 113, which is attached to the machine where required. The special feature of this machine is the series of rollers two to eight of small size, 8 in. and 10½ in., each having its own steam chest, as compared with the older type, known as the *Decoudoun,* in which there was one roller of 18 to 24 in. diameter, and one steam chest. For laundry use this type of machine is used for ironing and finishing at the same time as drying.

The cylinder is *perforated* or covered with wire mesh throughout in the type of dryer shown in Fig. 114, which shows the *Tumbler* dryer. Built somewhat on the lines of a modern washing machine, the cage is enclosed and receives a pressure blast of hot air through the battery of heating coils from above and below.

It is designed to treat feathers after they have been thoroughly rotated in a revolving barrel containing farina or starch. When placed in this *Feather Finisher,* the hot air gradually dries the feathers, while the rolling produced by the rack and pinion gear causes the starch to fall to the bottom of the machine, where it can be taken out.

A machine designed on similar lines is used to treat clothes from benzine cleaning and washing operations, and subject them to a temperature of 250° Fahr. by strong air current, thus removing moisture or fumes quickly, and with minimum handling.

CHAPTER X

EVAPORATIVE DRYING INSTALLATIONS

Drying Tunnels.—Characteristics—Progressive Drying—Typical Tunnel—Erith's Moist Air Tunnel—Tubular Tunnel—Summerscales' Pneumatic Fibre Dryer—Conveyor Tunnels—Keith-Blackman Suspension—Garment Clips—Rod Conveyor—Tension Conveyor—Wince and Cylinder Dryer—Ageing Machine—Hot Air and Cylinder Dryer—Superimposed Conveyor—Sutcliffe Soap Dryer—Sturtevant Progressive Timber Dryer—Brick Tunnel Dryers—Features and Types—Bland's Annular Tunnel—Sturm's Rotating Table Tunnel - - - - - - - 204-222

Drying Rooms.—Characteristics—Shew's Economic Room—Perkins' Room—Sturtevant Compartments—Seagrave-Bevington Room—Gibb's Harvester—Normal Air Process Room—Sutcliffe Confectionery Room - 222-233

Characteristics.—Tunnel dryers are of various designs, and essentially consist of a stationary tunnel or passage through which the material passes either continuously or intermittently as the drying proceeds. The passing of the material through the tunnel is an essential feature, although some dryers are called tunnel dryers in which the materials are placed on racks. This is not the correct term, as they are essentially drying-rooms, however long they may be. The drying in a tunnel is progressive from end to end, as in some cylinder dryers.

Structurally tunnels are longer than broad or high, and may be constructed of any material. In some instances the length is obtained by the imposition of one tunnel or part of a tunnel above or below another. The heat may be applied by direct firing or by heated air. The vapour may be removed by chimney, exhaust, or pressure fan, while the material may be handled in a very large variety of ways, some of which are special to the tunnel type. Taken generally, economy of heat and labour are well secured, but the first cost of the plant is sometimes high. The cylinder dryer has many of the characteristics of tunnel dryers, but the cylinder revolves, being cylindrical for that purpose, while tunnels are stationary.

The sectional elevation of *Erith's Patent Moist Air Tunnel* (Fig. 115) shows the typical form of a tunnel dryer, and has some prominent advantageous distinctive features of its own. As a tunnel it is a long building, through which the material passes progressively from the receiving end to the delivery. During its transit it is heated and dried by the heated air current. This air current is admitted at the delivery end, and passes back among the material to the receiving end, where a duct or chimney draws the vapour-laden air away.

The distinctive features are that (1) the material is carried on special trucks (Figs. 68 or 71) over a tram track over A, and passes through one truck length at a time to the delivery over C. (2) The heat is supplied from live or exhaust steam in the heater coil shown at D under the track. (3) The heated air passes upward among the nearly dried timber entirely by its decreased weight when heated. (4) The incoming heated air presses forward the previous supply, and thus keeps up a steady current from the heater. (5) The air becoming colder by heating the timber and vaporising the moisture, is consequently heavier, and gravitates into the space beneath the track E, and thence into the flue F. (6) Thus no fan or blower is needed, the air automatically warming the timber, vaporising the moisture, and removing the vapour, while the speed and degree of its performance can be entirely regulated by the steam valve of the heater.

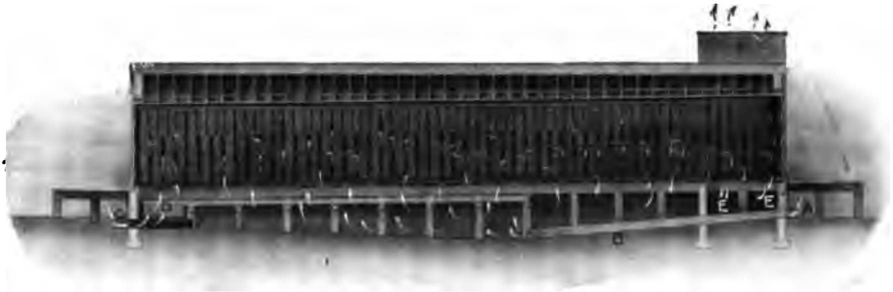


FIG. 115.—MOIST AIR TUNNEL DRYER (PATENT). SECTIONAL ELEVATION. (Erith's Engineering Co., Ltd.)

Having no moving parts no motive power is required, thus the initial cost and maintenance are very low. The steam is utilised to its utmost capacity, and such a dryer about 123 ft. long can give an output of ten standards daily, the period in the dryer varying from one week for pine and spruce deals, to three days for 1-in. pine boards. No labour is required in the drying chamber, and hence there is no need for the men to suffer from the humid atmosphere.

For a long tunnel dryer of the *Tubular* type, the one shown in Fig. 116 has some striking distinctive features as to its simplicity, small initial cost, and small floor space occupied. It was originally designed for short wools as they leave the washing bowl, and have to be carded, but can be used for fairly long wools and similar materials.

Taken seriatim as shown from right to left in the illustration, there are (1) the heater through which the air is drawn by (2) the fan of centrifugal blower type, blowing into (3) the galvanised iron duct, thus aspirating the material from (4) the suction hopper under the washing bowl, not shown. The air pressure carries the wool along the duct any reasonable distance into the (5) drying bin, where by (6) a specially designed rotating pocketed cylinder, the material is separated from the surplus air and delivered into (7) the swivelling outlet, while the air passes away through (8) the air outlet.

The installation is thus a continuous one, self-feeding and self-delivering, working under pressure or plenum throughout, entailing no labour and comparatively small power.

The heat is derived from a steam coil heater; it is applied very thoroughly and intimately during the passage along the duct and in the drying bin. If this duct passes over or through any extraneous heat, it also utilises that. The removal of the vapour takes place in the dryer bin, where the material is caught in the pocket of the receiving cylinder, while the air passes through their wire covering, and through the upper screen of the bin into the outlet duct.

Details of the receiving end are shown in Fig. 117, where C is the heater, B the fan, and A the roller delivery from the washing bowl. The arrows show the direction of the main air current, and the induced or aspirated action which serves as an automatic feed.

The delivery end is shown in detail at Fig. 118. The warmed

and partly dried wool carried along by the air under pressure comes into contact with the wire pockets formed in the

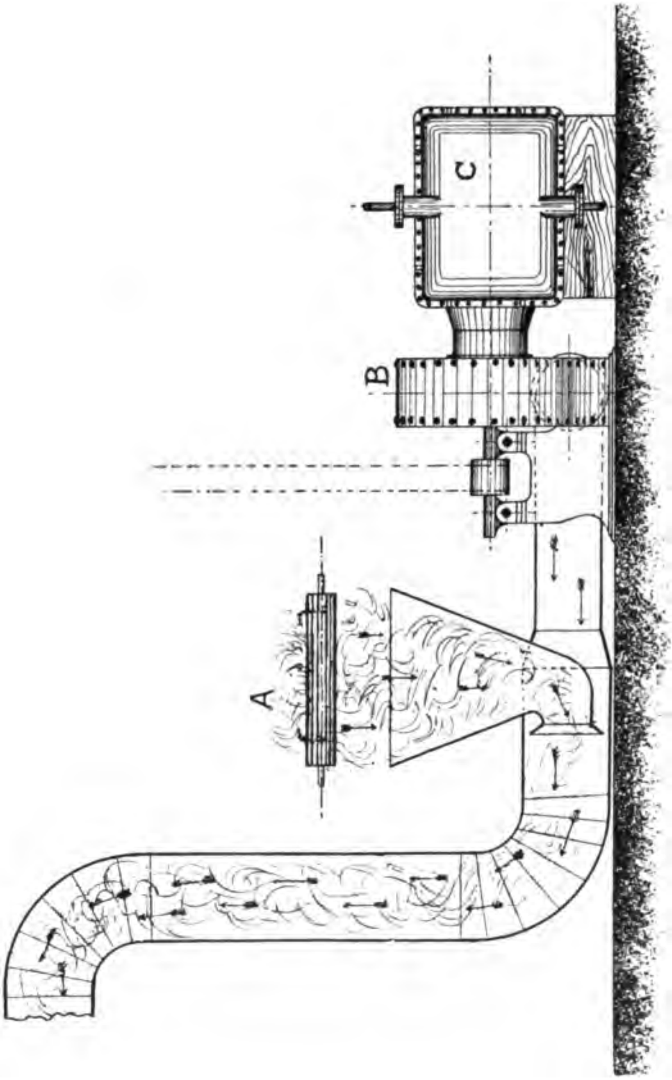


FIG. 117.—PNEUMATIC RECEIVING APPARATUS. SECTIONAL ELEVATION.
(W. Summerscales & Sons, Ltd.)

rotating cylinder D, and is carried round with warm air in contact at all surfaces. The wool being finally dropped into

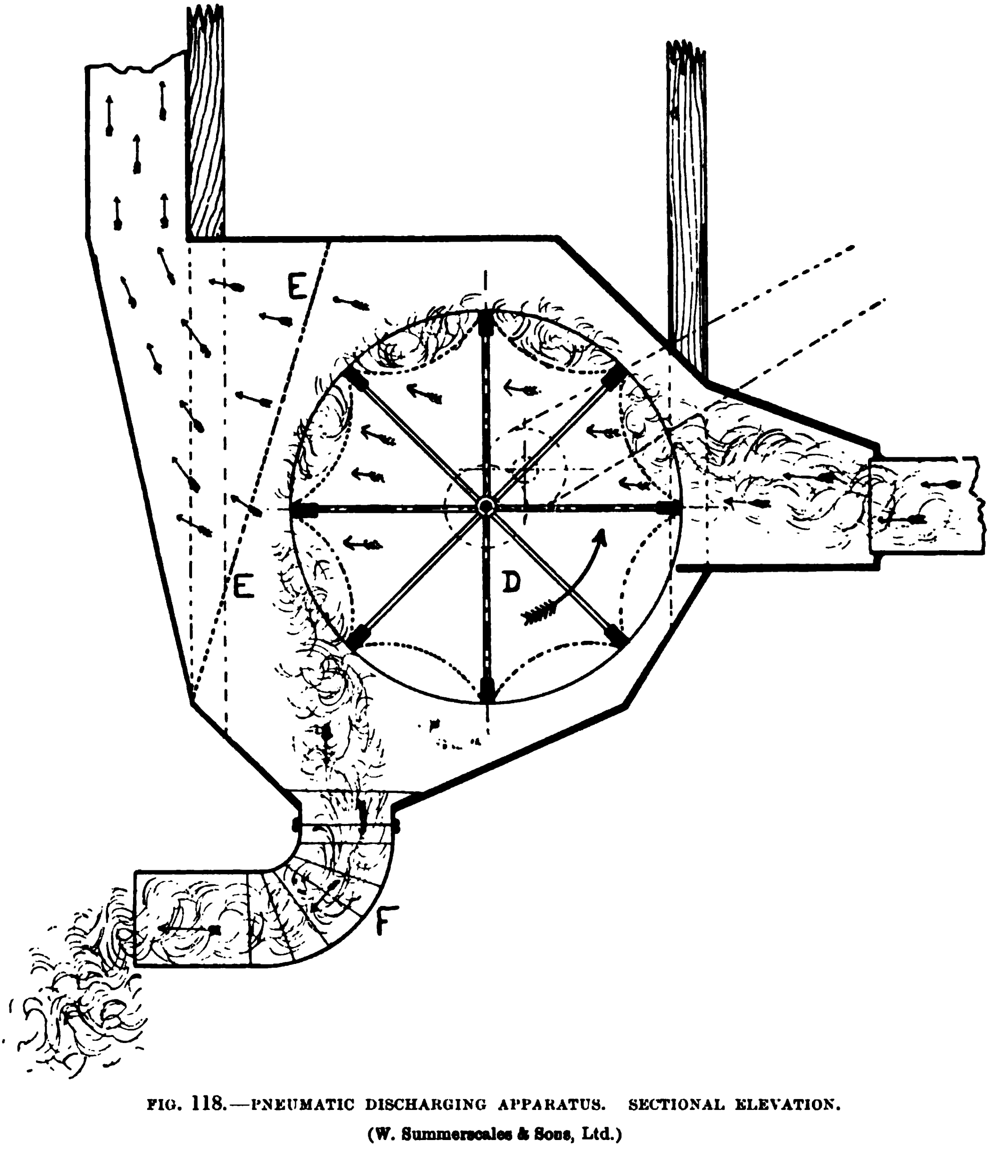
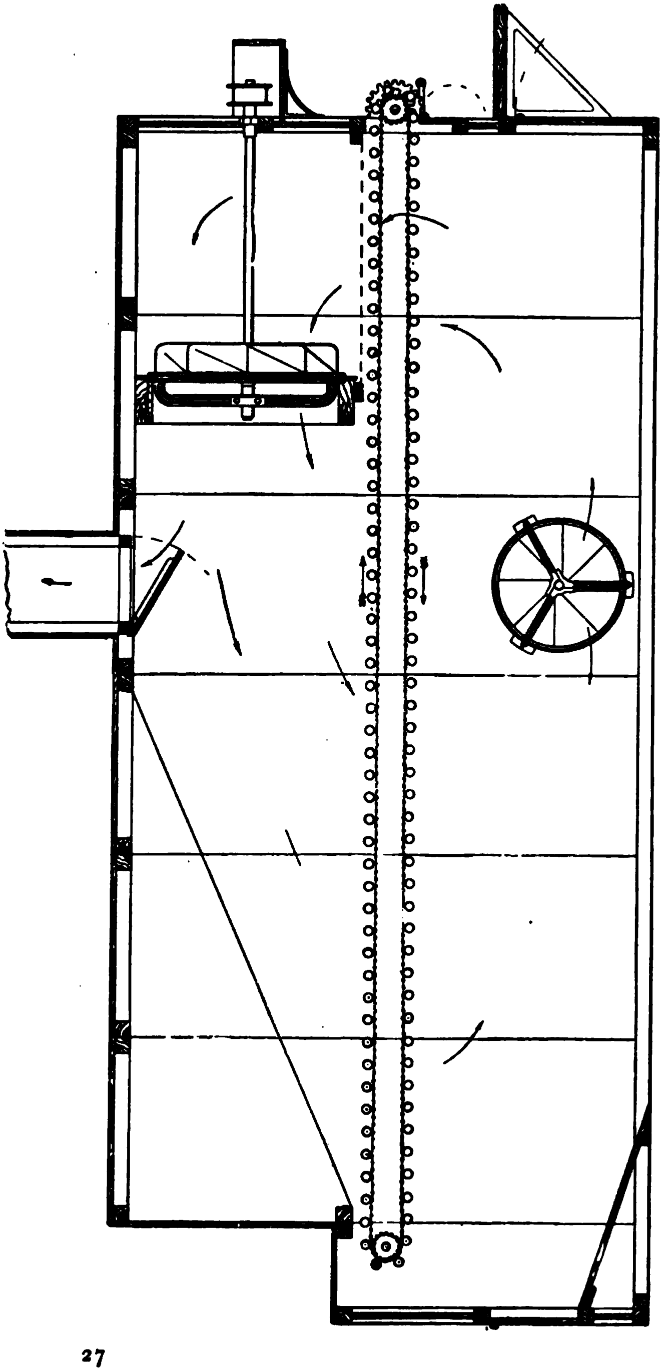


FIG. 118.—PNEUMATIC DISCHARGING APPARATUS. SECTIONAL ELEVATION.
(W. Summerscales & Sons, Ltd.)

the hoppered part of the bin and the swivelled shoot F, to be delivered where desired. The air has been thoroughly in contact and mixing with the material throughout its journey, and



SECTIONAL ELEVATION

FIG. 119.—DOUBLE CHAIN CONVEYOR DRYER.
(Jas. Keith & Blackman Co., Ltd.)

in the cylinder pockets. The light fibres are prevented from being lost by a screen E at the entrance to the outlet duct.

A tunnel dryer in which the whole gear is encased, while the material or goods to be dried are slowly *conveyed through a tunnel*, suspended from moving attachments, is illustrated in Fig. 119 by longitudinal sectional elevation. Fig. 120 shows the detail for attaching the goods, and Fig. 121 gives a plan of the same installation in part cut away to show the conveyor.

The plant consists of an endless double chain conveyor working on sprockets at each end. The chains are connected by round wooden bars having special attaching sleeves or clips for the garments. The whole mechanism is encased so that there are passages above and below. Into the lower passage a 24-in. propeller delivers air which has passed through the heater. In the upper passage two 36-in. propellers circulate the air from the lower passage, returning part of it again, and passing part into the open vent at the top.

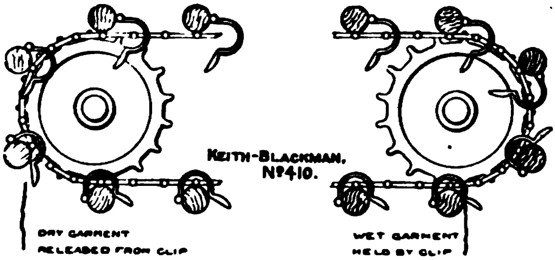


FIG. 120.—GARMENT CLIPS.
(Jas. Keith & Blackman Co., Ltd.)

The heat is thus supplied by the double heater enclosed in a louvred casing, and is applied by the propellers to the suspended materials or goods, the vapour being removed by the propellers, and expelled into the open.

The garments are hand fed on to the hooks till each bar is full, when the worker turns the small wheel to move the whole conveyor forward to the next bar. This bar is then loaded, attaching the garments by the clips shown in Fig. 120, of which there are enough to hang four shirts on each bar, or of other goods in proportion to their size. Again the wheel is turned a step forward and so on till the conveyor is full. When this first

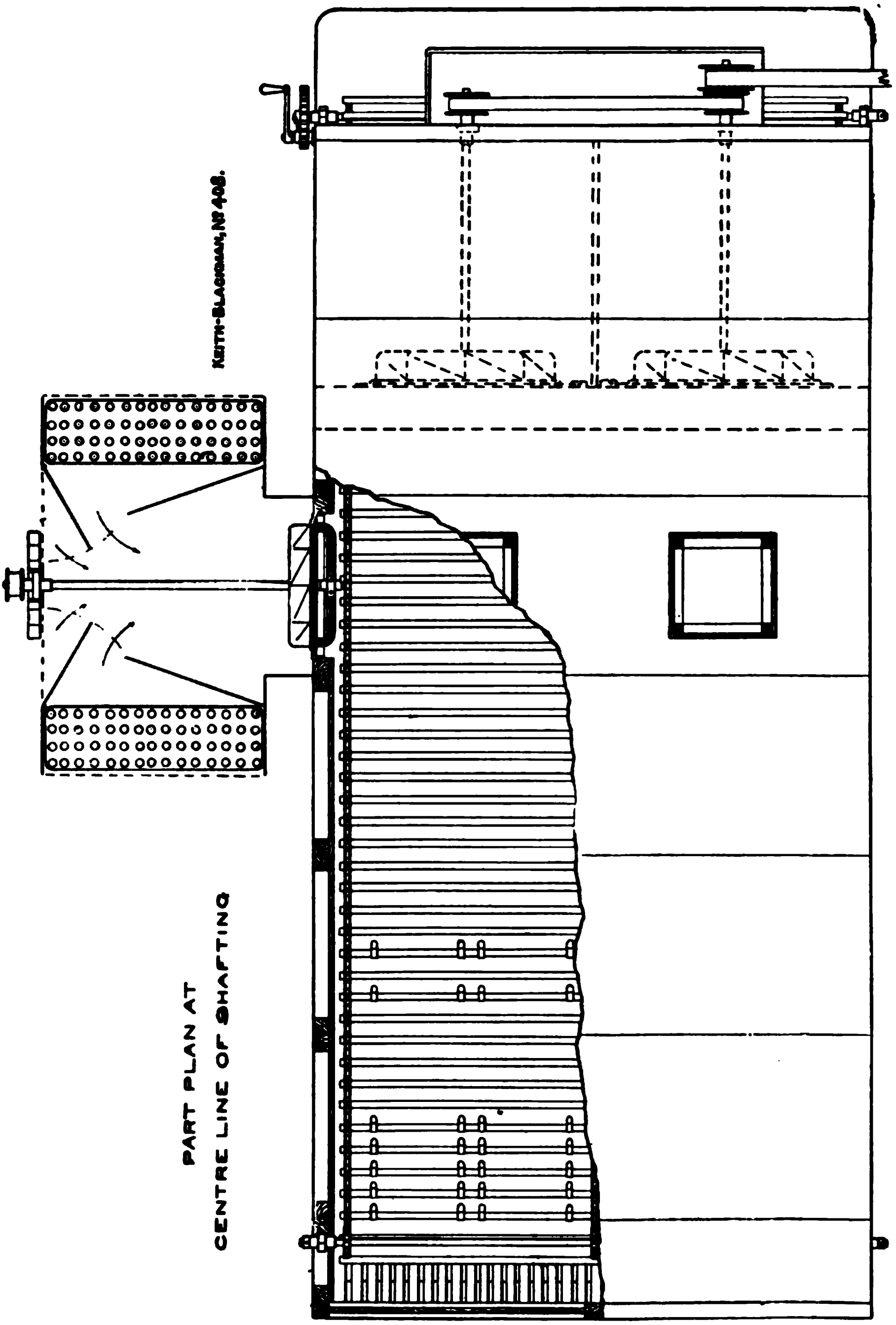


FIG. 121.—DOUBLE CHAIN CONVEYOR DRYER.
(Jas. Keith & Blackman Co., Ltd.)

load has been dried, as one bar is loaded at the feed end one bar is automatically unloaded at the delivery end. Thus the machine is kept full, ensuring the maximum drying without heat loss or interruptions. The heat adjustments can be set and maintained readily without risk of danger. In practice hydroed shirts require about twenty to thirty minutes. In public bath usage 270 huckaback or Turkish towels 54 in. by 27 in. can be dried per hour, leaving the desirable and natural rough surface, at an expenditure of 1 lb. of coal to every 4 lb. of water evaporated. It is adaptable for all laundry work, textile and hosiery factories, for paper or pasteboard in sheets, for light skins, and especially for garments or continuous webs not held in tension.

Dispensing with the clips (Fig. 120), and replacing the wooden bars by *polished wooden rods*, a conveyor similar to that illustrated by Figs. 119 and 121 can handle white or dyed wools with efficient results, while drying is performed on the system just described. Outside the dryer an automatic opening and loosening gear reaches the wool from the scouring bowls and delivers it on to the dryer conveyor. The dryer conveyor continuously passes it through the drying tunnel and delivers it automatically dried and opened out.

Dealing with Shropshire combing skin wool and using a temperature of 90° to 105° Fahr., a 30 ft. dryer of this make will dry 800 to 900 lb. per hour continuously without any handling or loss of heat.

Replacing the chain and wooden bars in the above machine by chains to carry stiffer bars placed wider apart and fitted with projecting wooden pins, it can be adapted for economically handling hanks of woollen or other yarns. Each hank is spread upon two pins by hand, and after drying is received on a bar (telescopic).

This machine is made in three sections, each 9 ft. 8 in. wide. The sections are built together according to requirements, some sections being used for cooling off after the drying. For instance, a floor space of 18 ft. by 9 ft. dried 320 lb. per hour (dry-weight), and a space 9 ft. by 9 ft. cooled them off. The approximate time for three-ply hanks in 1 lb. (dry) hanks with 100° Fahr. is 25½ minutes to dry and 9 minutes to cool.

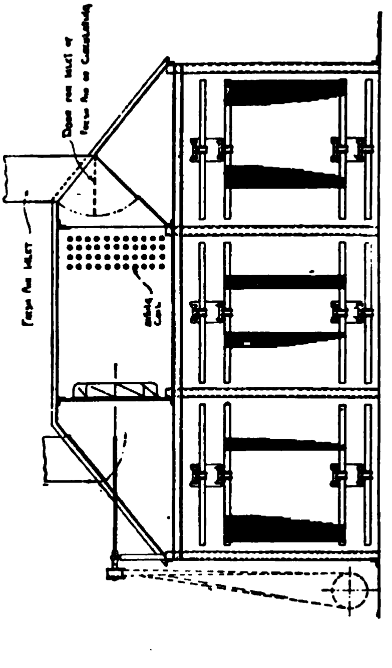


FIG. 122.—TRANSVERSE SECTION THROUGH BLOWING-IN FAN.

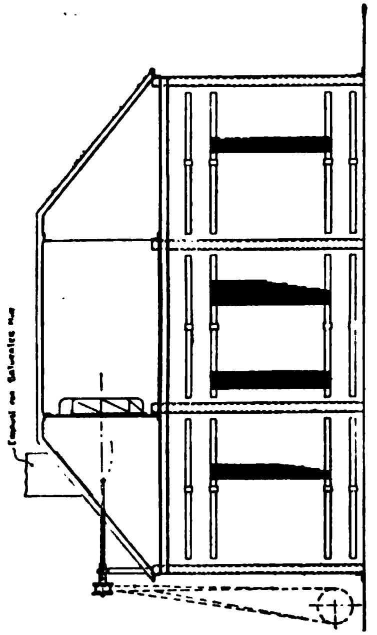


FIG. 123.—TRANSVERSE SECTION THROUGH CIRCULATING FAN

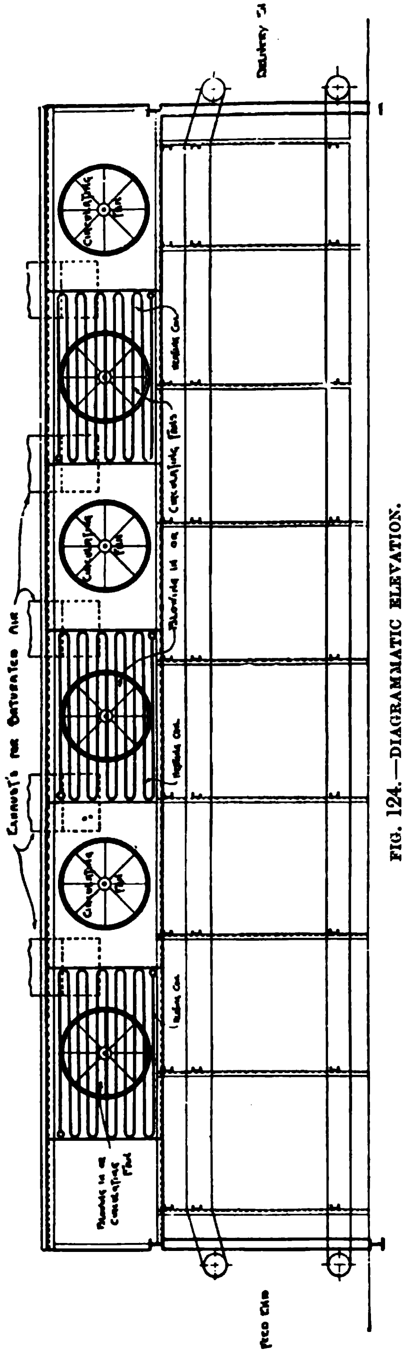

Delivery End
Circulating Fan
Heating Coil
Circulating Fans
Exhausts for Saturated Air
Blowing in or Circulating Fan
Heating Coil
Passage to Circulating Fan
Feed End

FIG. 124.—DIAGRAMMATIC ELEVATION.

TENSION CONVEYOR DRYER.

(Jas. Keith & Blackman Co., Ltd.)

In an actual test of a 9-section machine working 100° Fahr. the following results were obtained:—

Hanks = 1 lb. 6 oz. wet; 1 lb. dry.
Load = 17 bars each carrying 11 lb. (wet).
Dried = 40 bars per hour = 440 lb. wet = 320 lb. dry.
Water evaporated = 120 lb. per hour.
Steam condensed in heater = 240 lb. per hour.

For drying flax and other yarns while *held in tension*, the same system is employed with modification in structure and detail to accommodate the conditions. The diagrammatic elevations in Figs. 122 A, B, and C show the design of this form.

The machine is in sections; the illustration shows a plant of three sections. Each section contains two chain conveyors working on sprocket wheels, and carrying polished wooden poles, which, being held in the centre, leave free access for the yarns to be put on and off. Each pole in the top conveyor is fitted with cog and pinion which cause it to rotate, while each pole on the bottom conveyor fits in a sleeve which allows it to rotate. The upper loops of the hanks are placed over the ends of the lower pole on the top conveyor, and the lower loops of the hanks are placed over the ends of the upper poles of the bottom conveyor. The rotation of the poles of the top conveyor causes the hanks to revolve, and thus rotates the poles of the bottom conveyor. While the yarn is wet and the hanks revolving, they receive a series of sharp, regulated blows, which shake and straighten them. The inclination of top conveyor causes the increased tension during drying, and the decreased tension at the delivery end, so facilitating removal.

The drying at atmospheric pressure by large volumes of warm air, as will be seen, is by three sets of coils and three inlet propellers. The exhaust is by three more propellers. The coil and propellers are all at the top of dryer over the tunnel in which the wool is dried. The air is controlled in its circulation by various plates and valves.

The dryer is made in various sizes to dry 1 to 5 tons per hour, and differing in length according to the weight of the counts. The structural portion is sometimes of brick, but it can be enclosed as a self-contained machine when desirable.

A range of hollow winches and steam cylinders, similar to

Fig. 108, with an alternating range of winches and guide rollers superimposed above them, is used for gradual drying and "ageing" aniline black dye goods, where the drying must be gradual and large exposure is absolutely essential. The goods enter over swivel tension rails and pass over a number of hollow or skeleton winches before and after passing over the heated steam cylinders.

Guided upwards the goods then pass up and down a very large number of alternating skeleton winches and wooden return rollers, thus obtaining a series of vertical layers of material between and through which the rising air currents pass and "age" the goods.

The whole plant can be built into a room or enclosed, and gives great capacity in comparatively small space. It is a striking example of the economy of space in the tunnel type of dryers, forming a long exposure on the double row of alternating drums and still further extended by the vertical laps. The heat is thus very gradually applied, and being retained among the folds gets well saturated before passing out of the room. It can be worked by aeration or by induced exhaust of a propeller.

A tunnel-like range is also used for dealing with such delicate goods as cannot stand the sudden heat of contact with the cylinders. The first portion of the machine consists of skeleton winches in a double range placed horizontally over a battery of hot air pipes. When the material has been warmed and partially dried it is taken over the steam cylinders arranged in a double vertical range at the delivery end of the machine. By this method a progressive heating and drying is secured, while the vertical range also acts as an elevator for the material to the upper floors, besides economising floor space. The material is kept at an even tension and the power absorbed is merely nominal. When complete the goods are automatically plaited off in the usual manner.

In connection with the methods of handling the material on page 154, there is described and illustrated in Figs. 79 and 80 a type of *Conveyor used for a Tunnel Dryer*, in which the tunnel is extended by placing three conveyors one above another. In reference to this *Three-high Conveyor Tunnel Dryer* there are several points worth further consideration. The heat is supplied from steam pipe coils C, placed in double layers along the top of the structure. Two large propellers D are placed in the bottom of the structure, and draw air *via* the heater coils through the material and the canvas of the three conveyors. The heated air at 100° Fahr. is thus applied primarily where the material has most moisture, and is twice more drawn through the material, thus economising heat and utilising the compact form of the apparatus. The material is thus automatically exposed to the heated air for a length three times that of the structure, besides being twice gently turned over. The short circuiting of the air current is prevented by the canvas extending the entire width of the structure, and overlapping the angle carriers E.

The rollers F are used to regulate the feeder, and to guide the delivery into the special aspirating conveyor B, which receives its impetus from the fan H, and conducts the wool along the tube G, as described on page 206.

Having a large volume of air passing through at a low temperature strictly under positive control, this form of tunnel should suit any kind of wool or hair in an economical and efficient manner.

The *Sutcliffe Tunnel Dryer* is shown in the plan, Fig. 125, and in elevation, Fig. 126. As will be seen, the tunnel consists of four tracks, and these tracks are divided by walls into really four independent compartments each heated and exhausted by similar means. This partitioning into compartments is characteristic of most tunnel dryers and has great advantages in economy, range of heat, variety of product, &c., although some makers still retain the one compartment method for several tracks. In this installation the heat is supplied through tubular steam heater to the air fed into it by a direct-driven propeller. From the heater the hot air rises beneath the several tracks into the tunnel, through and among the material, which is almost ready for leaving the dryer. The air passes in the reverse direction to the material and leaves by outlet in the floor under the track, whence it is drawn by the exhaust propeller and discharged into the louvre roof. It is thus a plenum process with auxiliary exhaust to facilitate the vapour discharge. The material is handled by suitable trays on trucks which enter and leave progressively as the drying proceeds.

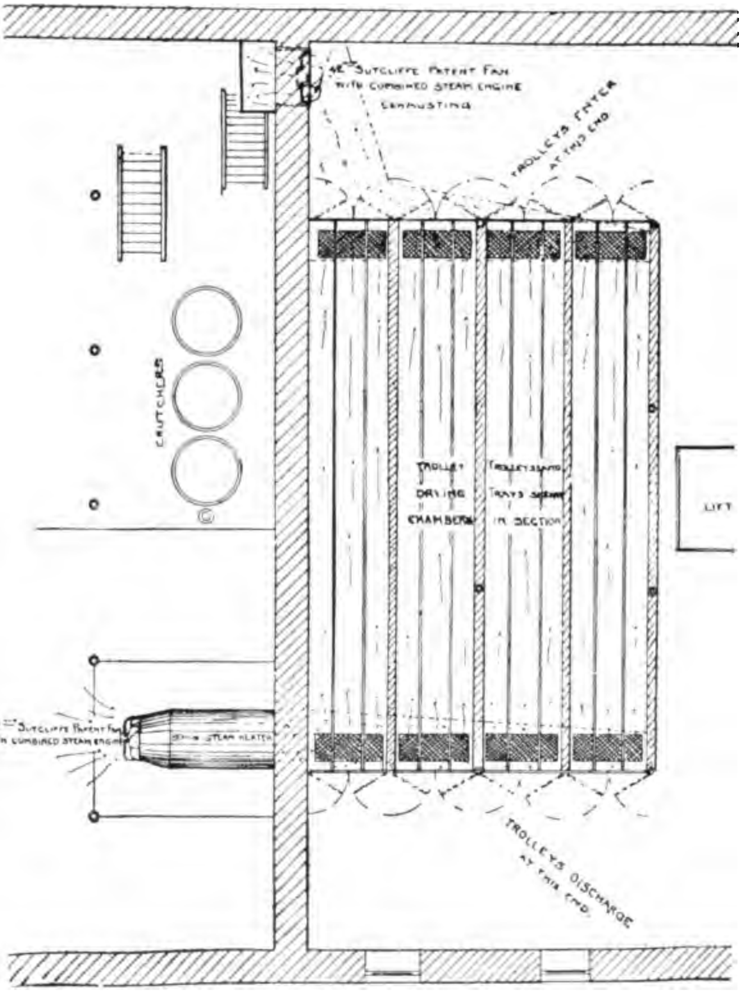


FIG. 125.—TUNNEL SOAP DRYER. PLAN.
(Sutcliffe Ventilating and Drying Co., Ltd.)

The entire tunnel is insulated apart from the buildings, and the valves for air and steam allow of varying temperatures in the several compartments. As applied to soap the temperatures

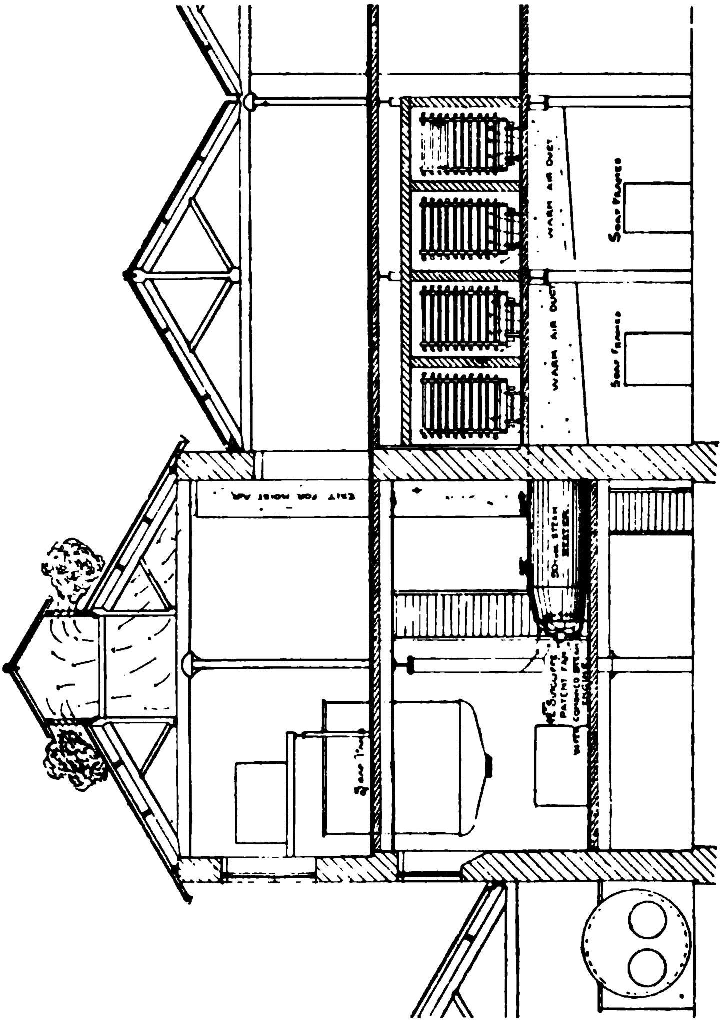


FIG. 126.—TUNNEL DRYER. ELEVATION IN PART SECTION.
(Sutcliffe Ventilating and Drying Co., Ltd.)

only vary from 70° to 100° Fahr. according to the kind, and the result is the surface drying needed to prevent future evaporation with consequent loss of weight. The extracting of the necessary

3 to 5 per cent. moisture from the surface while leaving the 35 per cent. moisture desired in the interior illustrates the adaptability of this dryer for materials which can be carried on trays or trolleys.

A tunnel drying plant divided into five tunnels for a large and regular output of material similar in size and thickness such as planks, is illustrated in the *Sturtevant Progressive Timber Dryer* (Fig. 127). From the cut-away portion of the view it will be at once apparent that in this system the ducts are fed with hot air at the delivery end from a heater and fan, as shown in Fig. 41. These ducts are so arranged that the air travels down the length of tunnels, while the material to be dried is passed through them in an opposite direction on suitable trucks. By means of this counter-current the damp material does not at first come in contact with the hottest air but is met by the comparatively cool and moist air that has already passed over the other trucks. As the contents of a truck become dry it is removed at the outlet end of the kiln, the remainder are moved along the tunnel and the space left at the opposite end is filled by a fresh truck. There is thus an intermittent "progression" of trucks through the tunnels as each truck load becomes dry.

The traversing bogie and the rails for handling the trucks are clearly shown. So are the counterbalanced entrance and exit doors to the several tunnels. From these it is obvious that the labour of handling is reduced to the minimum where quantities of similar materials have to be continuously dealt with.

Types and Features.—Tunnel dryers are largely in use in connection with the drying of bricks and clayware for which they are especially suitable and economical. Although the tunnel dryers shown in Fig. 115 or Fig. 125 might be taken as typical of the general construction of most brick tunnel dryers, the variations in design are really much greater than even the number of makers. There are, or rather have been, some tunnel dryers in connection with bricks of quite a different type, *e.g.*, Bland's annular tunnel dryer (see page 221) and Sturm's circular tunnel dryer (see page 222). Then there are some so-called tunnel brick dryers which are really long drying-rooms.

But returning to those warmed and ventilated tunnel dryers in which the material is moved and dried progressively, where the bricks are placed on trucks moving over rail tracks from one end to the other end of a long, well-protected building. In all other factors they vary, *i.e.*, as to warming, ventilating, moving of the material and structure of the building.

In the *structure* of the building there are—

1. Those in which the tracks are separated by division walls.
2. Those in which the whole of the tracks are in one undivided structure.

With regard to the *moving of the material*, there are—

1. Those in which the material travels in the same direction as the air currents.
2. Those in which the material travels in the reverse direction to the air currents.

The *ventilation* or *vapour removal* is by—

1. Exhaust fan with casual supply.
2. Pressure fan supply—
   (*a*) From above.
   (*b*) From below.
3. Pressure fan supply with exhaust, assisted by auxiliary fans.
4. Flues and chimney.

Warming offers a wide choice in sources of supply and methods of applying the heat. The various types are—

1. Direct firing with furnaces built in or under the tunnels, and allowing the products of combustion to pass through the tunnels and among the goods. This is quite on the kiln style, and left the bricks as well as the men in a dirty and sooty condition.
2. Direct firing with furnace and flues under the floor, which allowed of heat transmission but excluded all products of combustion.
3. Waste gases from the kilns and furnaces. These were used—
   (*a*) Alone.
   (*b*) As auxiliary to one of the other heat supplies.

of combustion at once distinguishes a room from a kiln, whereas the entry for loading, &c., marks it from an oven, while being enclosed differentiates it from a shed.

Structurally, apart from being entirely enclosed, there are no essential restrictions, but when not of brick or stone for economy the walls or casing should be chosen for its non-conducting qualities, save where lower temperatures than the surroundings are in use. A room may be on wheels or otherwise portable. The heat supply may be of any kind excepting the passage of the products of combustion. The method of applying the heat may be by any mode. The removal of the vapour is carried out in practically all the possible ways in one or other of the different drying-rooms.

The *handling* of the materials in rooms is generally an expensive process as being by manual labour, but in most cases this arises from the delicacy or other feature of the material itself not allowing of economical mechanical conveyance. The drying-room offers all the advantages and disadvantages of a drying-oven, except in so far as manual labour is used inside the drying-room, but not inside the drying space of an oven. Hence rooms are generally chosen for goods or materials which require hand labour, and the objectionable feature of entering the drying chambers has to be dealt with as an unavoidable necessity. They appear to particularly lend themselves to such goods as pottery and other clay wares, rubber crêpes and sheets, hops, textile fabrics, paper, leather, &c.

In many cases drying-rooms are used for other purposes when drying is proceeding, and hence have to be designed to meet other controlling conditions than those arising from drying; *e.g.*, in pottery works, crucible works, paper and textile mills.

Shew's Hop Drying-Room, as illustrated in part sectional elevation, Fig. 128, shows very clearly the essential difference between a kiln and a drying-room, at the same time demonstrating the more scientific methods now employed in drying hops. Instead of the arsenic and the products of combustion passing up through the floor and into the hops as in the old kiln method, here the fumes pass away and the clean heated air alone is used. The heat supply is by coke, coal, or other convenient fuel in Shew's ribbed radiating stove described on page 93 and illustrated in Fig. 47. The air is economically heated by the unusually large amount of radiating surface offered by the gills of the stove and the complete system of flue coils. The heated air passes through the usual perforated hop floor and hops either by its own expansive force or preferably assisted by a pressure fan, which is found in practice to double the output per hour.

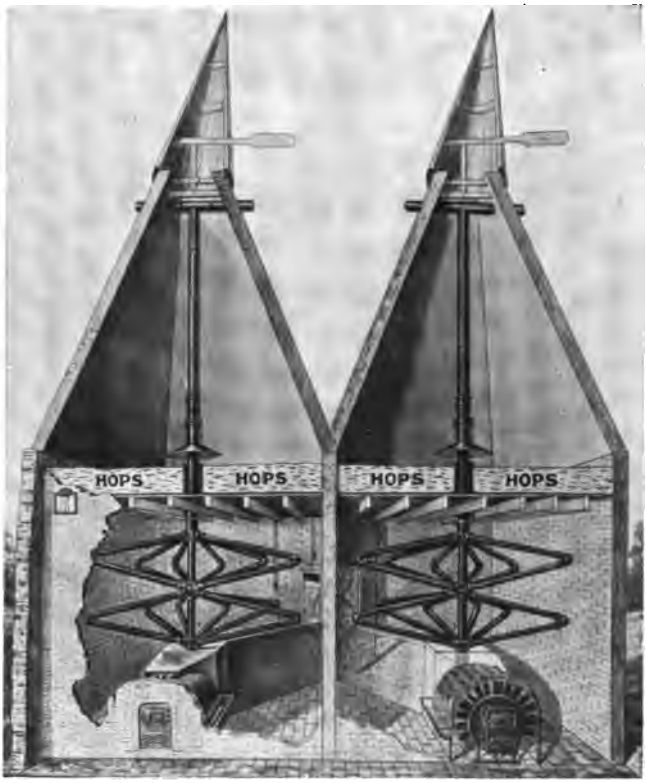


FIG. 128.—SHEW'S HOP DRYING-ROOMS (PATENT).
(Jones & Attwood, Ltd.)

The flue passing through the centre of the drying-room acts as a subsidiary assistance in removing the vapour while not in any way contaminating the air.

The material (hops) is handled as found most convenient in the usual hop kiln by manual labour. The output per square foot of floor space under fan air supply is 5 to 6 lb. of dry hops per twenty-four hours, with a fuel consumption of 15 cwt. to 1 ton per ton of hops, from which 75 per cent. moisture has been removed. Bearing in mind that 6 lb. of green hops produce only 1½ lb. of dried hops with 9·1 per cent. water of constitution, this is a delicate and difficult problem in drying for a hot air process.

Hop rooms are now also worked by steam-heated air from heaters of the radiating type fed with air by propeller fan. A well-designed installation of medium size working under 130° Fahr. will deal with 6 to 8 lb. of green hops per square foot of floor space in the working day of, say, ten hours, with 15 cwt. of fuel to the ton of dried hops.

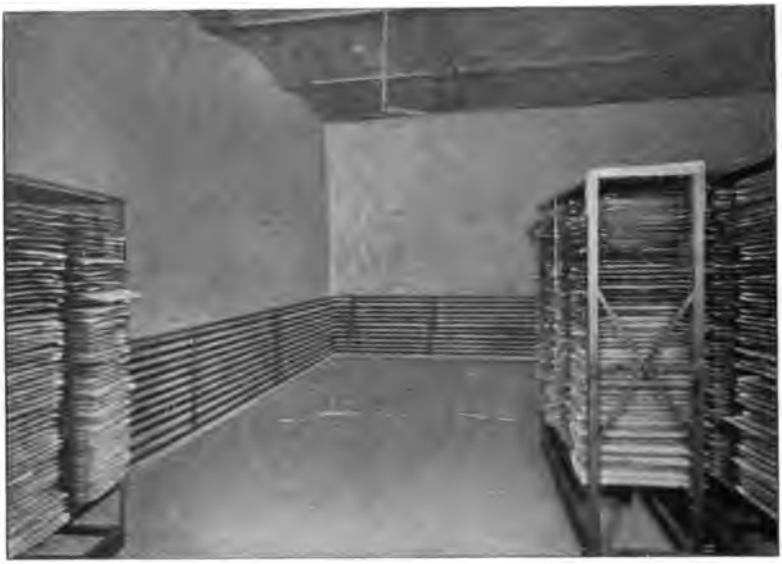


FIG. 129.—PERKINS' DRYING-ROOM.
(Werner, Pfleiderer, & Perkins, Ltd.)

The *Perkins' System*, as applied to drying-rooms, is shown in Fig. 129, the distinctive feature being the coils of small bore pipes heated by hot water in a closed circuit above atmospheric pressure. The action is thus positive and uniform. The same water is used permanently, as the coil in the furnace is a continuation of those in the room. The whole apparatus takes up but little space, while having the advantages of cleanliness and purity of air attaching to steam and hot water systems. Its adaptability to differing circumstances is very great; the illustration is of a room for drying printed tin plates, but the same process equally well heats a tunnel dryer or a drying oven where the material indicates their suitability.

The *Sturtevant Drying Rooms* are illustrated in the elevation, Fig. 130, and the plan, Fig. 131, by a four "compartment" plant, with air currents from side to side of each "compartment." This feature differentiates them from drying "tunnels," which have air currents from end to end, and progressive drying (see page 219).

The heating and circulation are produced and controlled by a tubular heater and pressure fan of ample

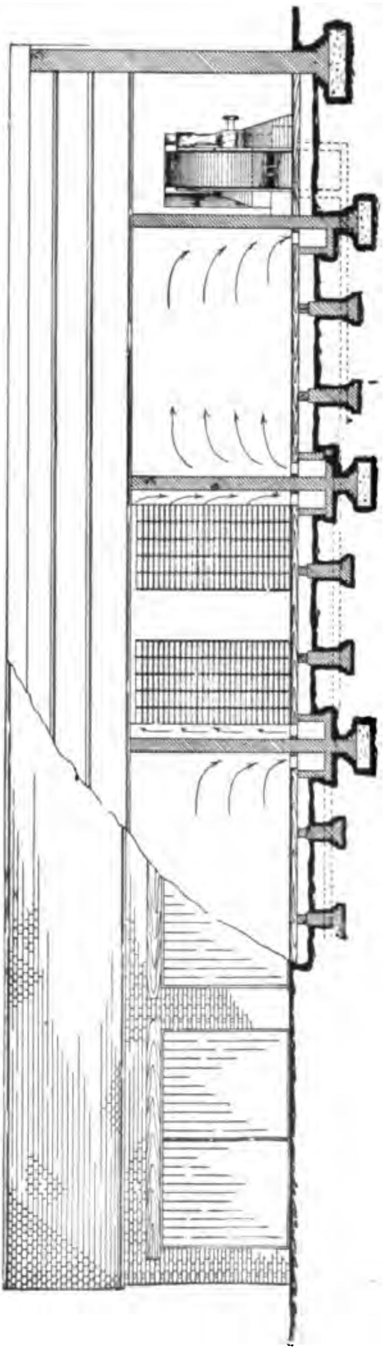


FIG. 130.—"COMPARTMENT" DRYING ROOMS. ELEVATION.
(Sturtevant Engineering Co., Ltd.)

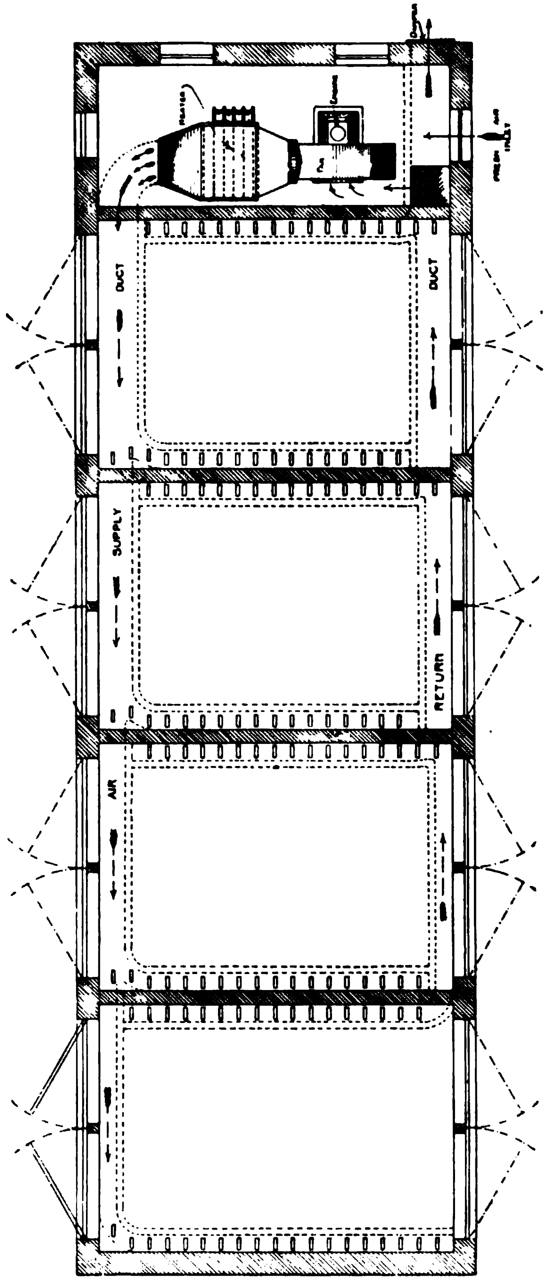


FIG. 131.—"COMPARTMENT" DRYING ROOMS. PLAN.
(Sturtevant Engineering Co. Ltd.)

capacity, as illustrated in Fig. 41. The fan blows the air through the heater, and by an under-delivery into the air supply duct which runs under the floors of the various compartments. Separate outlet valves regulate the supply of heated air from this duct into each "compartment" or room.

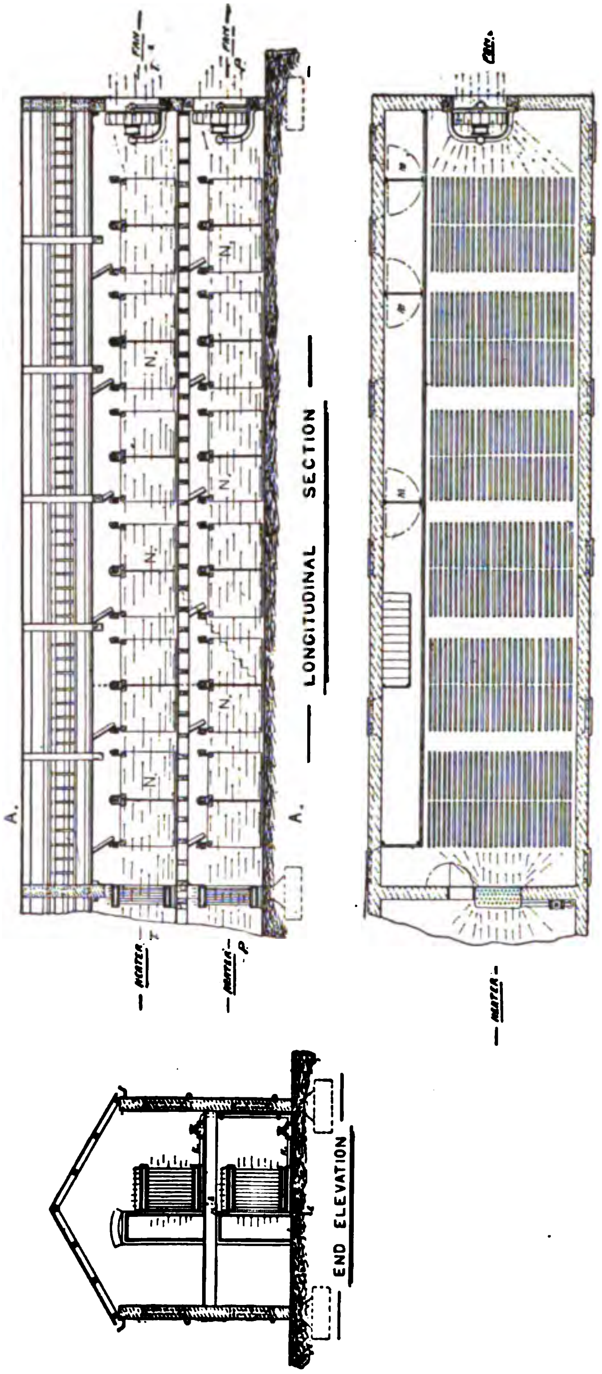
The heated air in the room is blown into, about, and through the material to the return air duct, which is on the opposite side of the rooms from the inlet in each room, and passes under the floor.

The common return air duct discharges partly into the open and partly into the receiving chamber for the fresh air. Thus only the air which has performed its vaporising duty is driven out.

The substantial nature of the structure and the insulation to prevent heat losses can be seen from the illustrations. Of course where the material is suitable for mechanical handling this plan is equally applicable to a drying oven. With the direct driven fan shown this makes a self-contained plant ready for connecting either exhaust or live steam. Usually it is exhaust steam in the day and live steam after the working hours for the remainder of the day and night.

The *Seagrave-Bevington Drying-Rooms* illustrated in Fig. 132 by plan, longitudinal and end elevations is worked on the exhaust process. It will be noted that the building has two floors which may be treated as distinct drying-rooms, hence it is only necessary to describe one. The leather, which is the material here under treatment, is pinned on to movable boards on runners, with access on each side and passages between the boards for the air currents. The portion which is under operation is partitioned off from the passages for conveying the materials.

The heat is supplied by a concentric tubular heater of the Seagrave-Bevington pattern described and illustrated on page 86, Fig. 40, placed at the end of the room. The air current is induced by large disc fans or propellers placed in the exterior wall at the opposite end of the room to the heater, thus dealing with the air after it has passed all the skins and got its burden of moisture. From what has already been said respecting the exhaust process it is apparent that there will be no other inlets or outlets needed than the heater and the fan. Near the



PLAN.

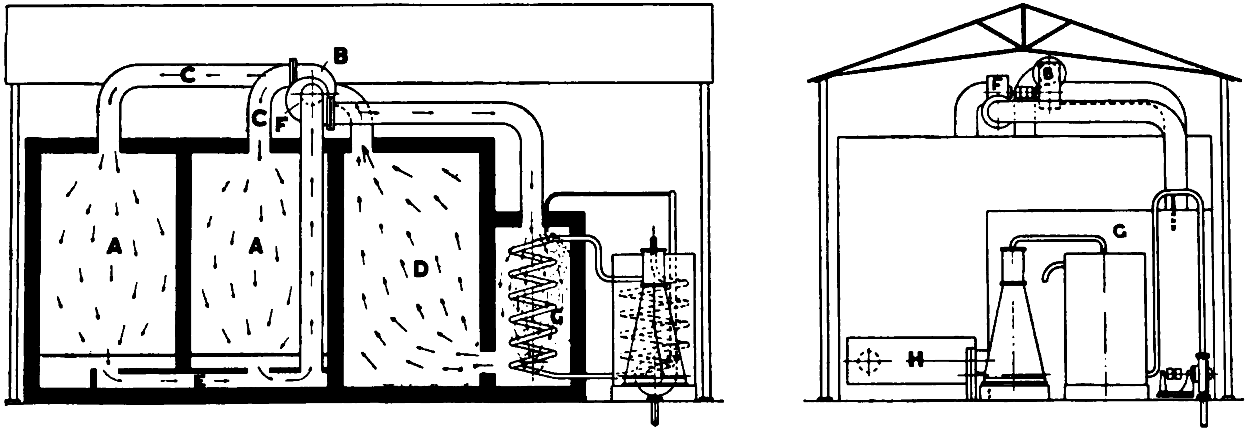
FIG. 132.—SEAGRAVE-BEVINGTON LEATHER DRYING-ROOMS.
(W. J. Fraser & Co., Ltd.)

heater is shown a cold air inlet valve to allow of the adjustment of the temperature in the supply, and there is a space left before the first group of hides for the air to properly mix. Although shown as in use for leather this design is also working on tobacco, &c.

Gibb's dryers for *harvesting* hay, corn, &c., which obtained the award from the Society of Arts, took the form of a portable room, or enclosed shed, with a false or double floor. The space between the two floors was used for the storage and passage of heated air used to warm the floor, and pass up through the perforations therein to the material. In the case of corn in "shooks," the heated current was more localised when passed through the floor by means of short vertical tubes, round which the "shooks" were stacked instead of the perforated floors used for haymaking and similar purposes. The heated air was supplied into this floor space by a fan having its inlet connected to a box which was heated by the exhaust steam and the flue gases from the portable engine used to drive the fan. The heater using both the flue gases and the exhaust steam gives very good results for fuel economy, and the entire plant was an economical one for the exacting conditions under which it worked. The room itself was built of light wood framing with louvred outlet at roof.

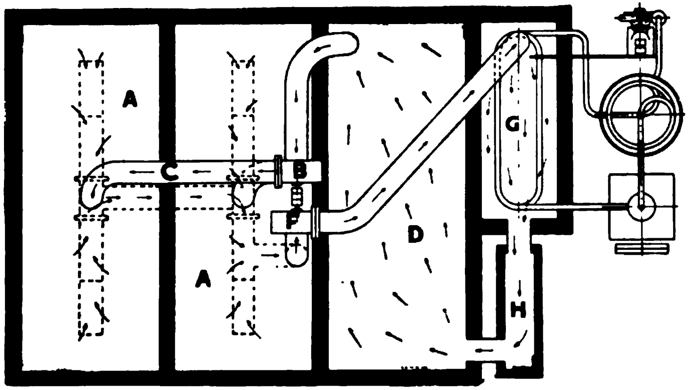
The *Normal Air Process* (*Marlow's patent*) is illustrated in Fig. 133 by plan, elevations, and end view, as applied to drying-rooms, although the same essentials can be adapted to use in drying ovens or drying tunnels, according as the material requires. The plant consists of (1) the air circulating fan with alternating current, (2) the vapour depositing gear, and (3) the heater. The special alternating twin fan has been described on page 125, and illustrated in Fig. 61. The vapour-depositing gear consists of an enclosed chamber containing cooling coils connected direct with a refrigerator, as described on page 27, and illustrated in Fig. 14. The heater is of the usual coil or radiator type used with exhaust or live steam. The material is hung or placed in the enclosed insulated chambers in a manner suitable for the greatest possible surface exposure of the rubber or other thermally sensitive substance.

The following cycle of operations is automatically and continuously performed:—(1) The exhaust fan F withdraws the



SECTIONAL ELEVATION.

END ELEVATION.



PLAN.

**NORMAL AIR PROCESS
OF DRYING
(Marlow's Patent).**

FIG. 133.—NORMAL AIR PROCESS ROOMS (PATENT).
ELEVATIONS AND PLAN.
(Pulsometer Engineering Co., Ltd.)

air from the drying chambers A, A, and delivers it into the depositing chamber G. (2) The coils cause an immediate deposit of water from this air. (3) The vapour-freed air is warmed in the steam heater H, and passes into storage in the equalising chamber D. (4) The warmed vapour-freed air is exhausted from the expansion, and forced into the already exhausted dry chamber by the pressure fan B. (5) This material is warmed, the moisture evaporated, and the operations (1) to (5) again repeated.

The results obtained are that the heat is supplied from the steam heater, and applied by air under pressure, hence obtaining positive and intimate contact at every possible point of surface. An interval obtains which allows of vaporisation. The vapour-laden air is then speedily removed by exhaust, which accelerates the vaporisation and increases the vapour removal. The burden of moisture is deposited in the cooling coils, and the cleansed vapour-freed air is heated just so much as it has been reduced by the vaporisation and the condensation of the vapour.

As all the ducts and chambers are insulated, the heat losses are small, while the available heat can be strictly regulated to suit the peculiarities of the special material. This process is a safe one for all temperatures, especially low temperatures, which are most difficult to deal with. It is also a particularly positive one, as the same air being continuously used in the circuit, there is no indefinite factor from changeable atmospheric conditions.

The *Sutcliffe Confectionery Drying-Room* is of the double compartment type, usually having drying chambers on each side of the heating and ventilating compartments. The plan and sectional elevation shown in Fig. 134 illustrate an eight-chamber plant for starch goods, pastilles, peel, or similar articles. Each chamber is about 25 ft. long by 8 ft. wide by 6 ft. 6 in. high to the false ceiling, holding 1,200 trays of the usual confectionery pattern placed in double lines on each side of the central passage. Each chamber can be treated as a separate drying-room, being connected or disconnected to the central air ducts. The hot air is blown down the central passage of each chamber, and can only escape through the narrow horizontal slots running behind the trays; it then rises

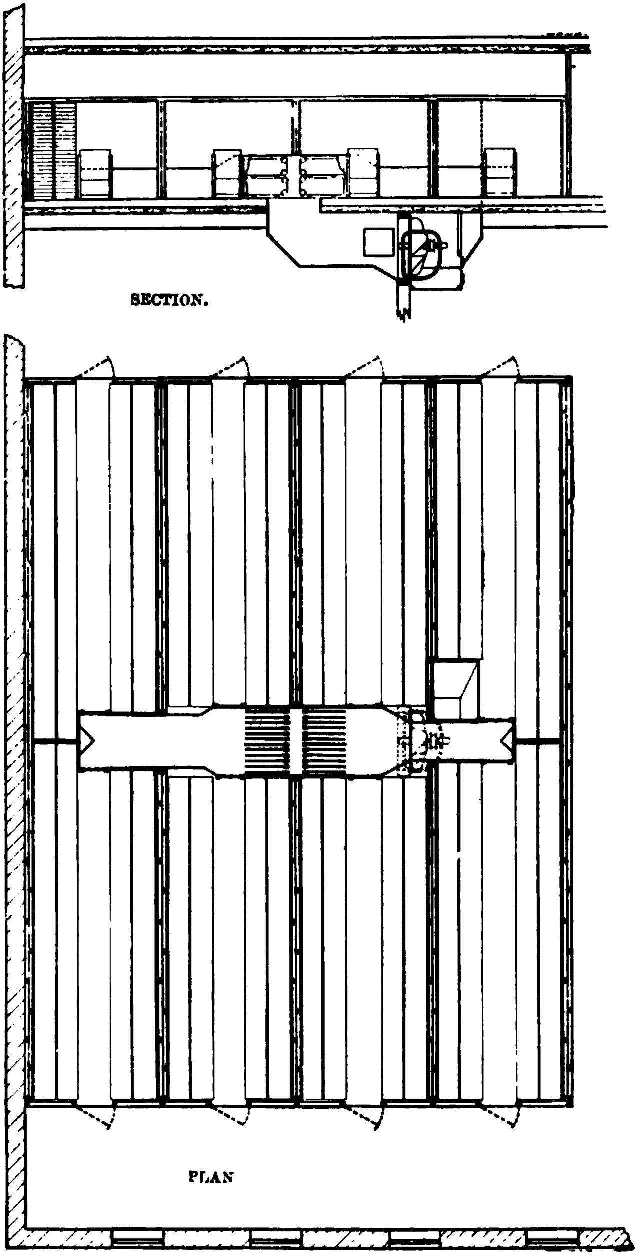


FIG. 134.—CONFECTIONERY DRYING ROOMS. PLAN AND SECTIONAL ELEVATION. (Sutcliffe Ventilating and Drying Co., Ltd.)

into the false ceiling above the rooms, and is returned either wholly or in part to the fan.

Such a plant is heated by stacks of Sutcliffe heating batteries containing in all 1,100 sq. ft. of heating surface, the air being supplied to the batteries under a slight pressure by a 48-in. propeller fan placed beneath the drying-rooms. The main feature of the system is the rapid circulation of hot air under gentle pressure throughout the entire plant and above each individual tray. The subdivision into compartments assists the maintenance of an even treatment with consequent regular product.

CHAPTER XI

EVAPORATIVE DRYING INSTALLATIONS

Drying Ovens.—Characteristics—Typical Ovens—Griffin Copper Air-Oven—Dentist's Water-Oven—Sirocco Tray Oven—Aerated—Exhausted—Pressure—Sirocco Tilted Tray—Sirocco Endless Chain Dryer—Turner Rotary Wheat Dryer—Hamel-Smith Rotary Dryer—Steam-Heated Hot Air Oven—Gnom Lifting Tray Dryer—Ryder Inclined Trays—Robson Agitated Trough—Lennox Plate Oven—Firman Agitated Oven—Carter Superimposed Agitated Troughs—Gardner Three-Tier Troughs—Imperial Grain Dryer—Fraser Removable Tray Oven—Wheat Conditioner—Sturtevant Laundry Oven—Sutcliffe Bottle Dryer—Scott's Stationary Vacuum Oven—Scott's (Patent) Vacuum Mixing Oven—Scott's (Patent) Vacuum Continuous Oven—Padding Machine and Hot Flue—Steam Chest and Hot Air Machine - - - - - - 234-266

Desiccators.—Characteristics—Scott's (Patent) Continuous Vacuum Desiccator—Milne Twin-Cylinder Desiccator—Boreas Portable Cable Desiccator—Blair's (Patent) Continuous-working Vacuum Desiccator - 266-272

Autoclaves.—Characteristics—Sutcliffe Sand-Lime Brick Autoclave—Delépine-Jones' Patent Pressure Current Disinfector—Volatile Oil Recovery Ovens - - - - - - - - - 272-278

Characteristics.—*Drying Ovens* are chambers or receptacles entirely enclosed adapted for applying heat, but not having the heat generated in them, or needing entry to charge or remove the material to be dried. An oven is distinguished from a shed by being entirely enclosed, from a kiln by not containing its own furnace, from a tunnel by being of any proportions, and from a room by the feed and discharge not needing the labour to enter. The range is very wide, and covers some of the most scientific and economically efficient dryers.

The heat being generated outside of the oven facilitates the exclusion of the products of combustion, and allows of the application either by radiation, conduction, or convection, generally, however, by a combination of two or all three of these methods of transmission. The heat losses may be minimised, as there is no necessity to cool down the room for entry, and for the same reason continuous working can also be readily obtained, although neither of these advantages apply in some cases, as the particular design may not provide facilities.

The applications of heat are made by hot gases heated from direct and waste sources, steam, live and exhaust, and by direct conduction through plates of radiant and steam carried heat.

The removal of the vapour is usually mechanical either under pressure or exhaust, but sometimes by aeration, while under this class also come the vacuum machines, which dispense with the air medium. The efficiency varies vastly with the different designs owing to their own characteristics, which are sometimes caused by the peculiarities of the material to be dried.

Taken generally, the oven should, when well designed, offer the best facilities of efficiency in fuel combustion, heat transmission, vaporisation, vapour removal, and handling expenses. As they are usually designed solely for drying operations and exclusively used for that purpose, higher efficiency is to be expected than in drying-rooms, which are frequently used for other purposes at times, if not at the same time.

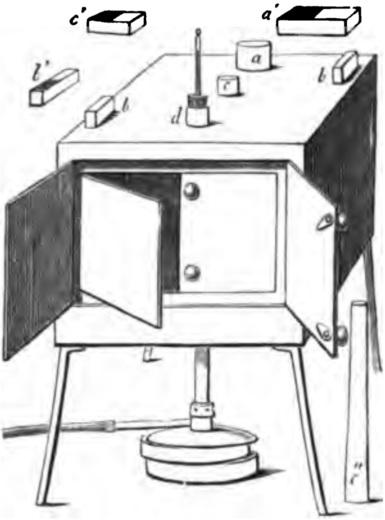


FIG. 135.—COPPER HOT-AIR OVEN.
(J. J. Griffin & Co., Ltd.)

Griffin's Copper Air Oven in iron jacket (Fig. 135) is for drying substances in a rapid current of hot air, kept within a few degrees of any desired temperature up to 500° Fahr. The apparatus consists of a copper chamber enclosed in a case made of stout sheet iron. There is a clear space of at least an inch all round between the copper chamber and the iron case.

The bottom of the iron case has a round hole in the middle rather wider than the head of the rose gas burner. This burner being lighted and applied there, air rushes up through the flame into the space between the copper chamber and the iron case and passes out by the chimney *a*. If it is desired to diminish the draught, the cap *a′* is put on the neck *a* and the gas burner can be regulated to vary the heat.

The copper chamber has a false bottom, formed by a shelf or stool that lies about an inch above the solid bottom. Each half of the space included between the two bottoms is open at one end and closed at the other, and the surface is perforated. Air passes into the enclosed spaces by two flat copper tubes, the upper ends of which are marked *b b*. The hot air after passing over the materials escapes by the openings *c* and *d*, either of which forms a convenient position for the thermometer, while on the other may be fixed the vent *c′* shown at the side.

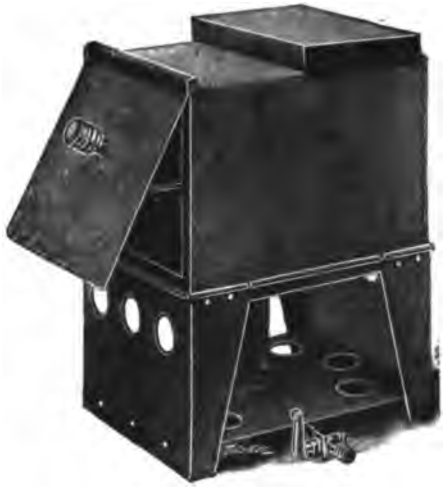


FIG. 136.—WATER-JACKETED DRY OVEN. (Fletcher, Russell, & Co., Ltd.)

Dentist's Water-Jacketed Dry Oven (Fig. 136) is specially designed for dentists' use. It is of heavy copper throughout, riveted and seamed joints for continuous hard usage. Besides the hanging door it has two sliding shelves of copper plate, hammered, tinned, and polished to fit over the water filling hole for warming rubber.

Heating is by gas burner and the hot gases do not enter the chamber at all, the jacket between the outer casing and the inner oven being filled with water. This is intended for temperatures below 212° Fahr., and for thoroughly drying off small quantities of water from solid moulds, casts, &c.

The *Sirocco Up-Draught Removable Tray Dryer*, as illustrated in Fig. 137, is worked by direct firing in a furnace of the multitubular type illustrated by Fig. 46 and described on page 92. This furnace, besides supplying the heat for vaporising, also produces the air current which aerates the material. Thus while the flue gases pass up the central passage of the chimney the vitiated air escapes by the annular duct around it, shown in part cut-away section on the illustration. As will be seen, on top of the heater is the drying chamber with a number of trays for the reception of the material.

Each of the trays has a separate slide and is independent of the others. Each column of trays has its own regulating damper for the hot air, while there are shut-off dampers to divert the hot air when required. The method of working is progressive, the wet material being put into the top tray of the column and then passed downward stepwise to the bottom slide for completion.

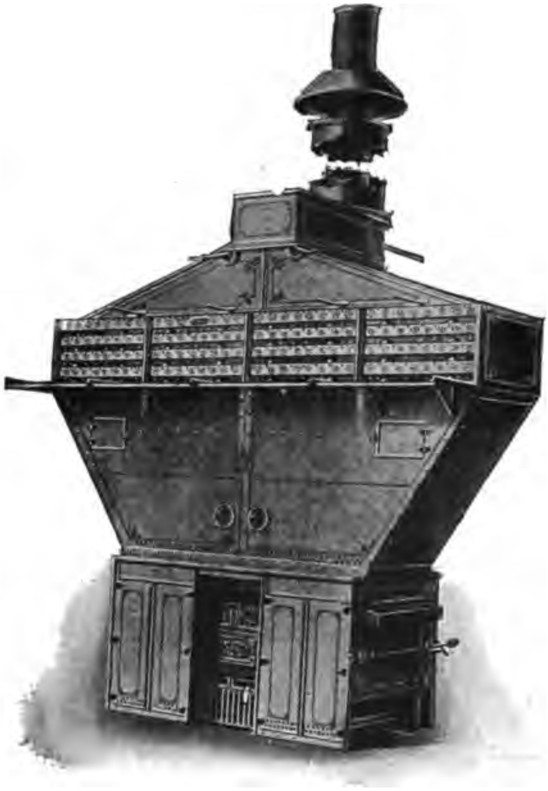


FIG. 137.—SIROCCO UP-DRAUGHT REMOVABLE TRAY OVEN.
(Davidson & Co., Ltd.)

This makes a self-contained dryer without any need for motive power or steam, being built up in sections and readily transportable. It is made in various sizes and capacities. Thus for a good wither of tea down to 60 per cent., using good fuel and a temperature of 220° to 230° Fahr., the makers give the capacities as per hour:—

4 tray vertical flue heater,	40 lb.
8 ,, ,, ,,	60 lb.
16 ,, ,, ,,	90 to 100 lb., multitubular.
16 tray multitubular heater,	100 to 110 lb.
20 ,, ,, ,,	120 to 130 lb.

The drawers or trays can be arranged endwise or at the front as illustrated. This type can also be used for cinchona bark, cocoa, coffee, &c., by having deeper trays with roller runners to carry the extra weight.

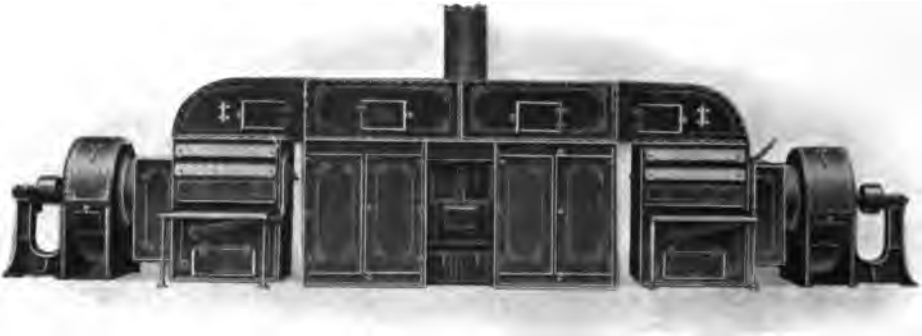


FIG. 138.—SIROCCO DOWN-DRAUGHT REMOVABLE TRAY OVEN.
(Davidson & Co., Ltd.)

The *Sirocco Down-Draught Removable Tray Dryer* illustrated in Fig. 138, while using the same type of multitubular heater as in Fig. 46, by means of the two centrifugal fans draws the pure hot air down on each side through the material into the fans, and away by separate ducts. In other essentials this dryer works on the same principle as Fig. 137, but by the down draught there is considerable saving in height, while the double induced draught gives more positive control, and naturally larger output. The two fans enable subdivision of working, which allows of many conveniences, while the large fans allow of slow speeds and small motive power. This type is made in various sizes, single and double draught. The low drawers give increased facility of handling.

The *Sirocco Tilting-Tray Pressure Dryer* is built and worked on similar principles to those described for the preceding sirocco tray dryers, except that these trays tilt, and the air is under pressure. The trays, four in number, and superimposed, are operated by turning a crank handle. This, through gear wheels and cam, causes each line of trays to tilt in successive order from the horizontal to the vertical position, beginning with the lowest line, the contents of which are discharged into the base of the dryer. The base also acts as an air-pressure chamber, but during the tilting the air pressure is shut off to allow the material to fall freely. All the gear is outside the machine, and easily worked by a lad, taking about six to eight seconds between each time of tilting.

The hot air is driven into the base of the dryer, and then upwards through the material on the four trays to the vent for the vitiated air at the top. The output is considerably more than the removable tray type.

The *Sirocco Endless Chain Pressure Dryer* works on the plenum system. It has three endless webs with narrow perforated trays supported at each end by the travelling chains. Thus the material traverses six times the length of the drying chamber, falling from one row to the lower. The material is fed in at the top, mechanically spread to even depth, and automatically discharged into the receiving hopper at the base. Throughout its traverse it is passing through an upward pressure current of hot air from a multitubular air heater.

The power to drive the fan and gearing for the conveyor chains is only 3 to 3½ H.P. The pressure causes a more even and regular drying of the material, besides greatly increasing the output. As in the other Sirocco machines, it is self-contained and easily transportable.

The *Turner Rotary Wheat Dryer and Conditioner*, illustrated in Fig. 139, works with a double air current, the upper being hot air to dry the wheat and the lower cold to cool and condition it. As will be at once noted from the print the feed, action, and delivery are all automatic and continuous. The wheat glides in a steady motion between the perforated cylinder and liner, from the top to the bottom, and is subjected to the blast as shown by the arrows. The gear drive is shown at the top, but may be at the foot where preferable. The footstep bearing is noticeable as ensuring steady working with small power. The amount of floor space occupied is very small, while the adjustments of air pressure, temperatures, speed of rotation, and rate of delivery each give a wide range of capacity to suit varying conditions of the wheat.

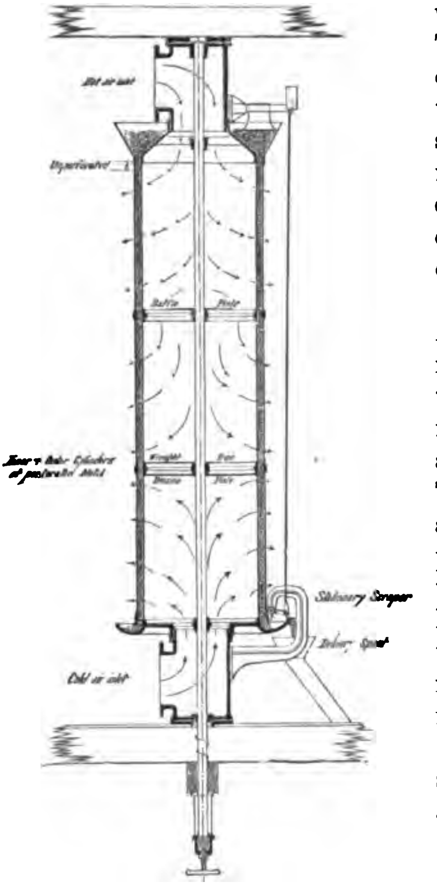


FIG. 139.—TURNER ROTARY WHEAT CONDITIONER (PATENT).
(E. R. & F. Turner, Ltd.)

The *Hamel-Smith Rotary Dryer* consists of a number of removable cylinders A, held in the periphery of a revolving frame. This frame is enclosed and situated over a furnace. The cylinders vary in number and size according to the output required, but in each case they are perforated and have ledges to lift the material as the frame rotates, while they remain stationary relatively to it. The frame is rotated either by hand, with the handle shown, or by a belt from a small motor. All other parts being fixed, no further power is required. The furnace can burn any fuel as the fumes pass up the chimney and do not come in contact with the air to be heated, or the material to be dried. The print is self-explanatory as to the ready means of handling the cylinders and the material. The firing and circulating arrangements are also clearly shown.

A compact self-contained form of *Steam-heated Hot Air*

Oven is illustrated in Fig. 141, where a series of trays or shelves have the air drawn over them by the propeller. The heating is by means of the small bore steam coils around, through which the air is drawn on the one side of the oven. The outlet is on the opposite side, while the material is placed through the doors shown at the front. It is designed for use on plantations, &c., too small to instal a vacuum plant, and where the amount of heat required is not enough to justify larger outlay.

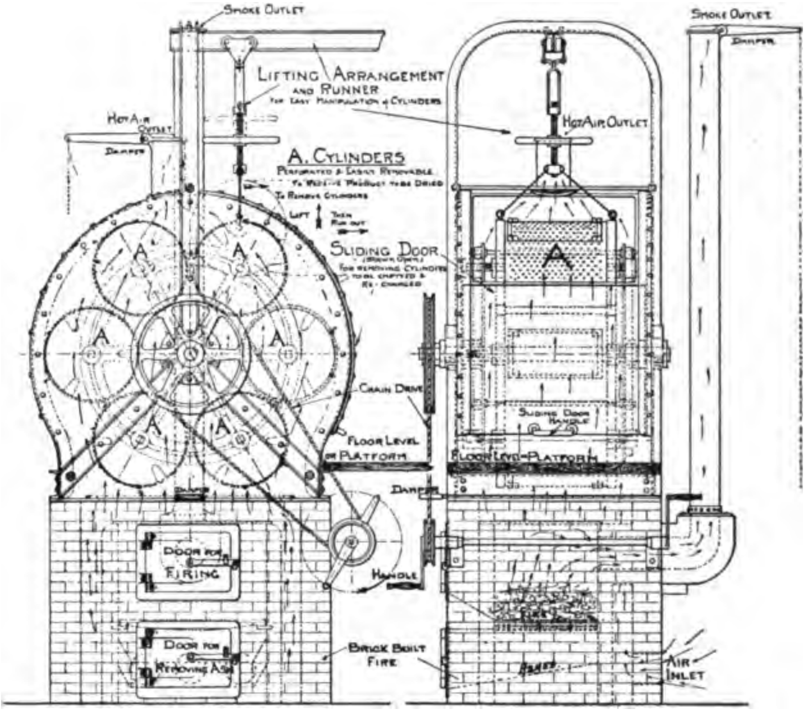


FIG. 140.—HAMEL-SMITH ROTARY DRYER (PATENT).

(David Bridge & Co., Ltd.)

A very compact portable drying oven made in several sizes for fruit and vegetables is the *Gnom Dryer*, illustrated in Fig. 142, with its own furnace attached, but it may be worked over an ordinary cooking range or stove. As will be seen, the oven is built up of thirteen removable interchangeable trays, which can be raised or lowered by a rack B and pinion P through two compound levers A, A, worked by the hand lever C.

The trays consist of a light wooden rectangular frame, with a bottom of corrugated wire netting, to facilitate the passage of the heated air through the whole of the trays and around the material. The projections shown on the trays are for inserting a light iron rod under and into the notches *n* in the wrought-iron frame; by this means any number of the trays may be lifted, and one or more withdrawn. The furnace F, shown in the vertical section, is a cast-iron rectangular box with gills to

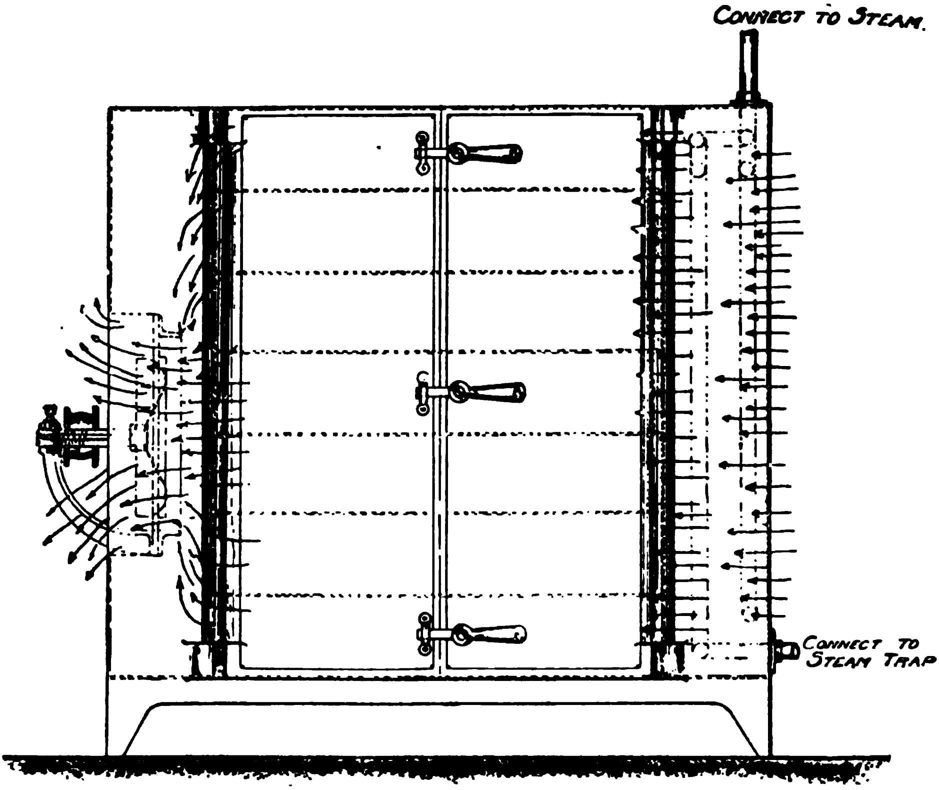


FIG. 141.—STEAM-HEATED HOT AIR OVEN.
(David Bridge & Co., Ltd.)

increase the radiating surface. The furnace is enclosed in a lagged air space with iron sides which form the base for the oven. The admission and direction of the air currents are shown by the arrows, while the deflector is placed just beneath the thermometer T.

It is usually worked by inserting the wet material in the bottom tray and raising upwards in the direction of the air currents which do not come in contact with any of the products of combustion.

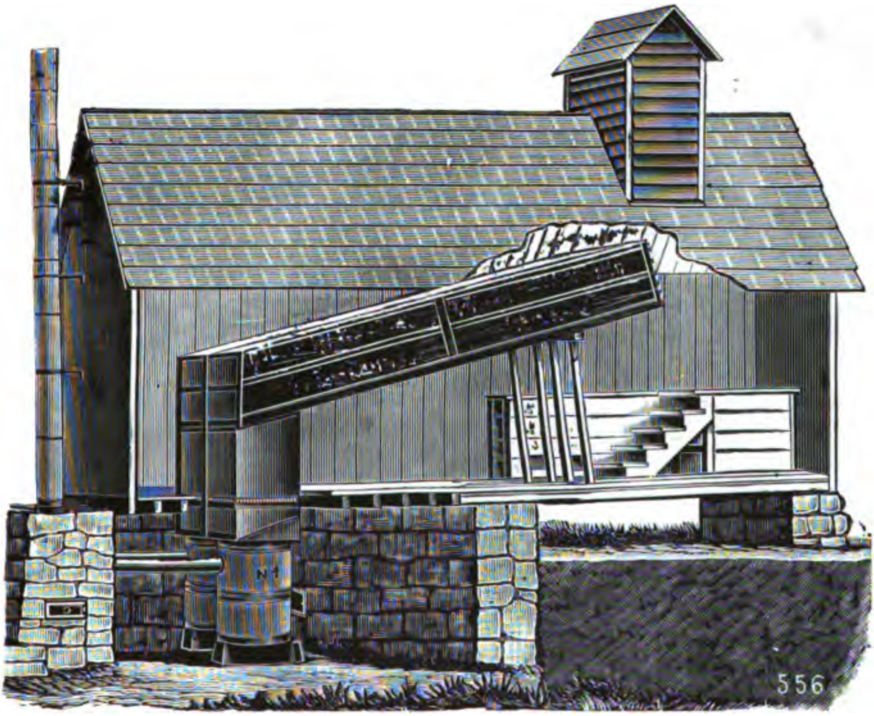


FIG. 143.—RYDER INCLINED TRAY DRYER.
(Mayfarth & Co.)

The illustration, Fig. 143, shows a complete installation on the *Dr Ryder system* of a *hot air* drying plant with inclined trays. The plant consists of the heating furnace with flue, the hot air reservoir, and the inclined trays. The stove can burn coke, coal, or any dry fuel, as none of the products of combustion mix with the hot air, and the flue can be taken outside the building as shown. The hot air reservoir is above the stoves, and has inlets for the fresh air, which when heated passes into the lower part of the inclined trays, and the material to the upper part.

The drying chamber is built up of a series of superimposed trays with perforated bottoms, which allows the hot air to obtain access to all parts of the material to be dried. It is specially designed to deal with fruits, vegetables, &c. Working by direct heating and aeration it forms a simple and easily erected means of drying or desiccating.

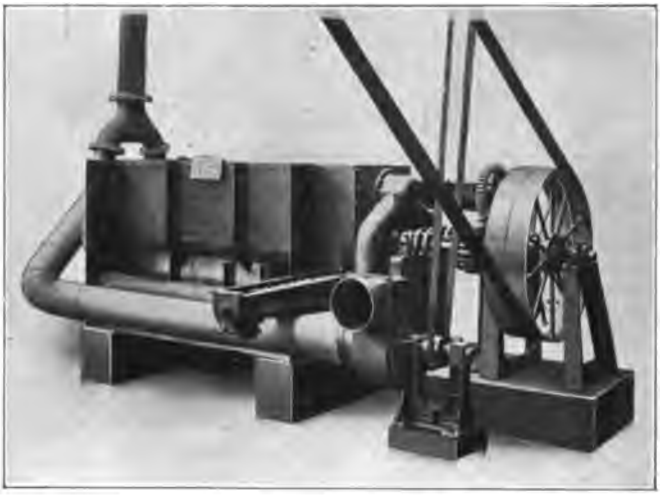


FIG. 144.—AGITATED TROUGH DRYER. GENERAL VIEW.
(G. Robson & Co.)

The *Robson Agitated Trough Dryer*, shown in Fig. 144, is a deep U shaped trough B with a double row of beater arms C continuously stirring and moving forward the material.

The material is automatically led by spiral A into the top of the enclosed trough B, and falls into the beaters. As the agitation proceeds the material repeatedly comes in contact with the heated sides of the trough, and is at the same time being exhausted by the centrifugal fan. The delivery is automatic into the worm conveyor shown. The heating is by coal, coke, or wood in the furnace D beneath the trough, and the flues are extended past the fire bridge and returned in cast-iron pipes reconnected in the breech pipe which forms the updraft shown in the far end of Fig. 144. It is especially designed for handling powders or granular materials which require agitation and will stand direct-fired plate heating. The fuel consumption is light, about 1 lb. coke to 6 lb. of water when dealing with materials having about 30 per cent. moisture.

The power is applied by belt drive through reduction gearing to the stirrer shafts. The fan is driven by small independent belt. When erected, the machine can be bricked in or not as desired for economy, but is built to work as a self-contained dryer with automatic feed, agitation, and delivery. The economy of fuel is well maintained by the return flue E, E, and the heat spaces H. The allowance for expansion and contraction at varying temperatures is provided for by the adjustable couplings to the shafts of the beaters C, C.

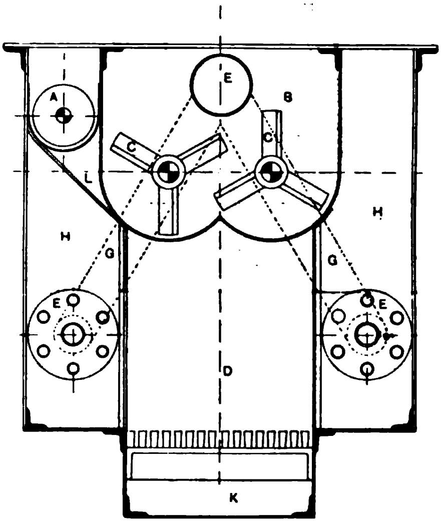


FIG. 145.—AGITATED TROUGH DRYER. SECTIONAL ELEVATION. (G. Robson & Co.)

The section, Fig. 145, is taken through the centre of the machine looking from the far end of Fig. 144, and the pipe E and breech pipes G, G, form the suction outlet to the fan.

The *Lennox Plate Oven Dryer*, shown in Fig. 146 by elevation and part section, and in Fig. 147 by plan and part section, is a type of dryer which has many advantages for suitable material. Among these advantages, compactness and the small floor space occupied are very conspicuous.

Although cylindrical in shape the outer case does not revolve, hence this is not a cylinder dryer. This outer case is

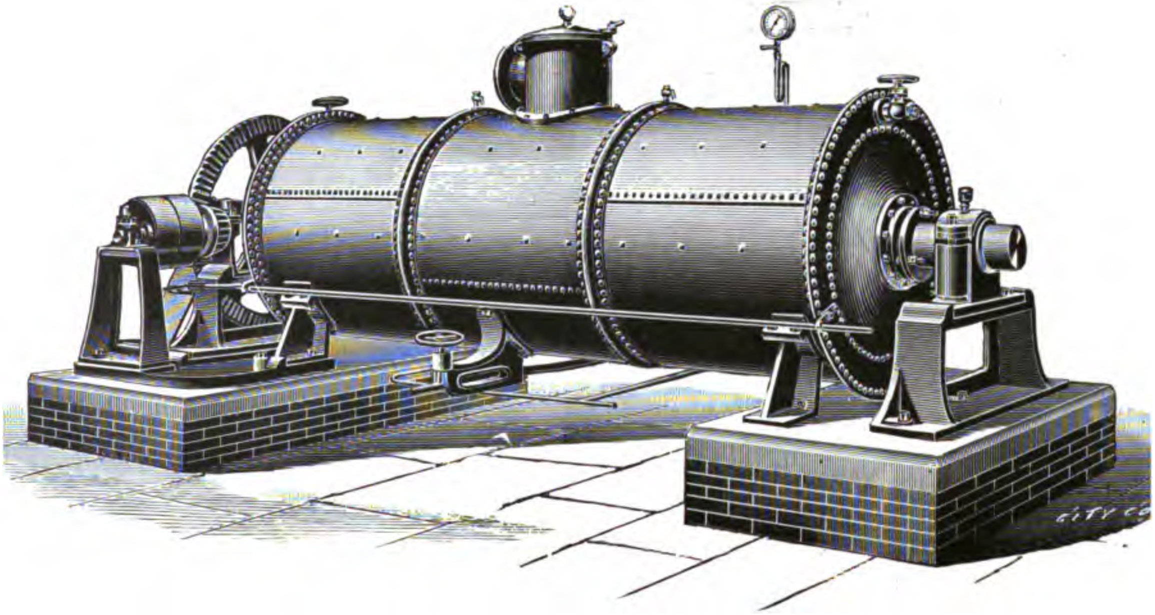


FIG. 148.—FIRMAN AGITATED OVEN DRYER. GENERAL VIEW.
(Manlove, Alliott, & Co., Ltd.)

gases or by pressure fan blast, while if the material is heavy an exhaust fan may also be used at the top. It will be noticed that the air current is in opposite direction to the flow of the material. Of course this allows of very close drying, but with materials which will not permit of this the air current could be controlled by pressure in the downwards direction with the flow of the material. The working mechanism is by spur gearing on to the central vertical shaft which rotates slowly and with small power.

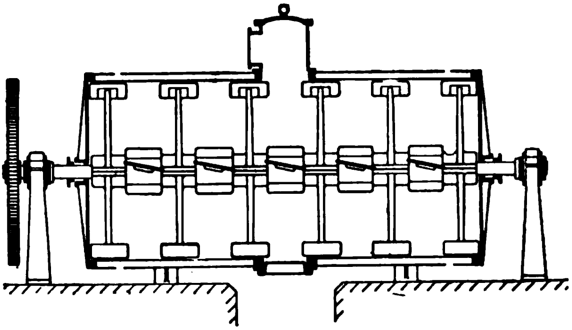


FIG. 149.—FIRMAN AGITATED OVEN DRYER. LONGITUDINAL SECTION. (Manlove, Alliott, & Co., Ltd.)

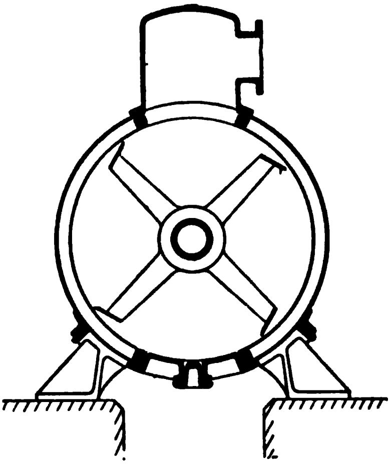


FIG. 150.—FIRMAN AGITATED OVEN DRYER. TRANSVERSE SECTION. (Manlove, Alliott, & Co., Ltd.)

The *Firman Agitated Oven Dryer*, although of cylindrical form, does not rotate, the outer casing being stationary while the central shaft with its beaters revolves inside it, as will be seen in the two sectional elevations, Figs. 149 and 150. The machine, as shown in the general view, Fig. 148, is a self-contained belt-driven one, but may have its own engine.

The casing consists of a horizontal steam-jacketed cylinder of steel plate with inlet, outlet, and gauge for the steam. It has removable covers for feeding and discharging the material. The steam and vapour are abstracted through a large outlet duct either by fan or pump according to the material.

The agitating gear is very powerful and thorough, continuously sweeping the entire internal circumference of the cylinder with a series of special blades on strong arms connected by massive bosses to the central shaft. This slowly rotating shaft is driven by spur reduction wheels and pinion. The material may be fed in at the top while the machine is running, and is kept in constant motion, being lifted, turned over, and falling continuously, thus coming into frequent contact with the steam heated surfaces, liberating the vapours as well as warming thoroughly all over. When dried, the manhole cover at the bottom can be removed and the machine will automatically discharge itself into truck beneath.

The steam heating allows of careful adjustment to suit each material, while the exhaust if offensive can be condensed and made innocuous. The machine is designed for dealing with wet pasty materials such as meat, fish, &c., whether fresh or foul, and forms a suitable machine to follow the Johnstone pan dryer described on page 168, Figs. 82 and 83. The usual sizes are 13 ft. by 4 ft. and 13 ft. by 6 ft., carry good loads, and generally take eight hours for each charge. While receiving the charge as semi-liquid or pasty solids, these machines deliver them as mealy powders, more or less fine according to their nature, and quite free from objectionable odours.

The *Agitated Trough Oven Dryer*, shown in Fig. 151 by a general view, is of a built-up sectional design having three or any other number of troughs superimposed upon each other.

Each trough is of steel plate and steam jacketed with agitators revolving on its own central shaft. The agitator blade also slowly conveys the material, which on reaching the end drops into the next lower trough and is conveyed in the opposite direction. The material is thus continuously being brought into contact with the heated surfaces and exposed to the atmosphere, thus the vapour is removed by aeration as the troughs are open.

The steam, either live or exhaust, can be fed into each jacket direct or pass from the top one to the lower and so on into the steam trap. When open in all directions the heat losses are considerable, but these may be avoided by casing in and using forced draught.

The gearing for driving the agitator shaft is so arranged that the central one drives the upper and lower by spur gearing, thus ensuring uniformity in speed and feed.

This type of machine is specially suitable for granular materials, powders, &c., which do not cake or paste up. The heat and speed being of a positive supply nature, can be interregulated to suit a wide range of requirements.

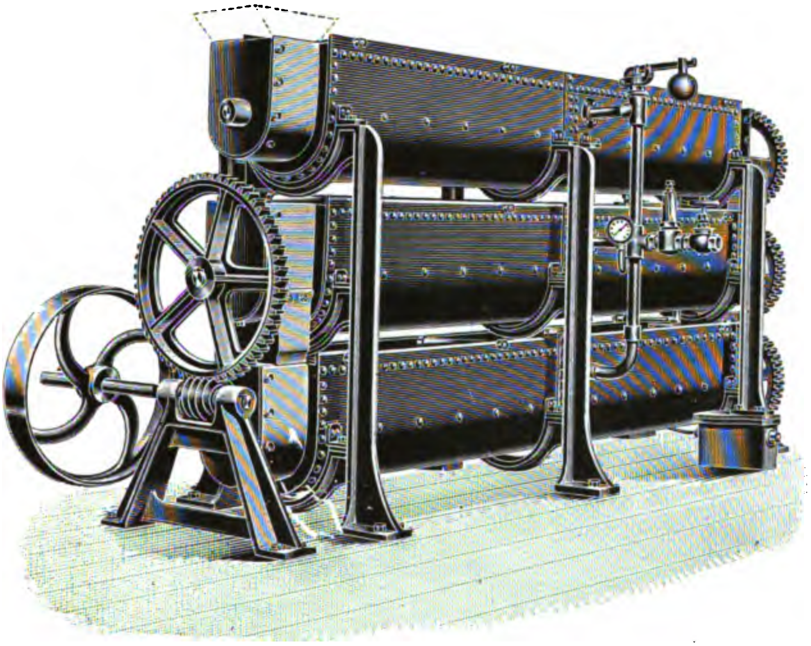


FIG. 151.—AGITATED TROUGH OVEN DRYER. GENERAL VIEW.
(J. Harrison Carter, Ltd.)

The *Gardner* (*Patent*) *Rapid Three-Tier Trough Dryer* is generally of the same construction as Fig. 151, but in place of the agitator blades has patent two-pitch mixer spirals in each trough. The ends, too, are interchangeable castings to which the steel trough is attached.

In Fig. 152 is illustrated the *Imperial (Patent) Trough Dryer* with complete covering and automatic feed screw. It is specially designed for grains, meal, sewage sludge, and similar materials. The trough is built up of strong cast-iron sections and tested to 160 lbs. per square inch although intended to work at 90 lbs. per square inch.

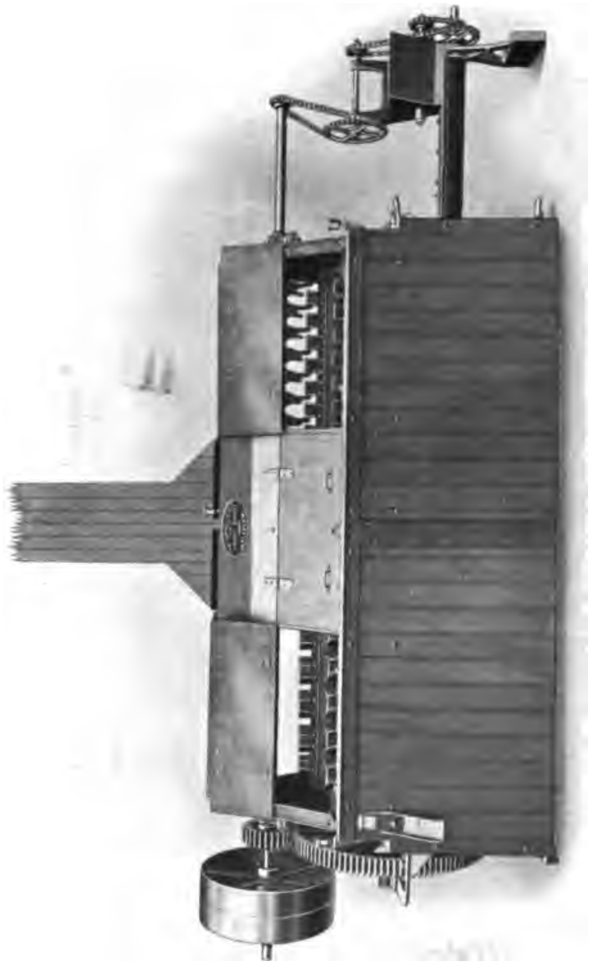


FIG. 152.—IMPERIAL (PATENT) TROUGH DRYER.
(Blair, Campbell, & M'Lean, Ltd.)

By means of the special shovels the material is brought continually in contact with the inner heating surface, while the outer heating surface is utilised to warm a current of hot air which also passes over the material.

The open brass doors show the internal construction and the special arrangement of rotating beaters at the feed (or wet) end which loosen the wet material and make it more accessible to the air currents. When used for distillers' grains and dregs the shovels, bolts, and other fittings are of a special mixture of gun-metal to prevent corrosion and wear. The bearings are of bronze and readily accessible. The whole gear is automatic and driven by one belt. The thorough agitation of the material and the complete intimate contact with heated surfaces and hot air enables a rapid drying with a mealy product. The machine is self-contained and needs no foundation.

The *Fraser Removable Tray Dryer*, shown in Fig. 153, works under pressure hot air from a steam heater. The steam heater is of the Seagrave-Bevington type described on page 86, Fig. 40, the air being blown through by a centrifugal fan, which forces it through the nest of trays into the exhaust duct at the far end. The trays vary according to the material, and are fitted in nests of entirely enclosed oven sections. These sections can be assembled to the required capacity and worked as one machine. The entire machine is very compact, light, and transportable. Live or exhaust steam may be used, while the fan requires but small power.

The *Wheat Dryer and Conditioner* shown in Fig. 154 is designed to further dry wheat which has been washed and passed through the whizzer (Fig. 28), the purpose being to draw the internal moisture from the centre of the berry to the outside skin. The general view, Fig. 154, and the two sectional elevations, Fig. 155, A and B, have the appearance of the mechanism being much more complicated than is really the case. The machine consists of two vertical steel casings A and B, down which the corn gravitates from the two feed hoppers to the two delivery spouts. In each casing there are at intervals louvres D, which somewhat check the fall, cause the corn to turn over, and act as vents for the air currents from the hot air chamber E by the inlets L, and to the fan ducts G by the outlets M. In the casing A is a row of steam pipes C, which warm the grain by conduction, while in the foot of the machine is a steam chest or battery of pipes F, which heat the incoming

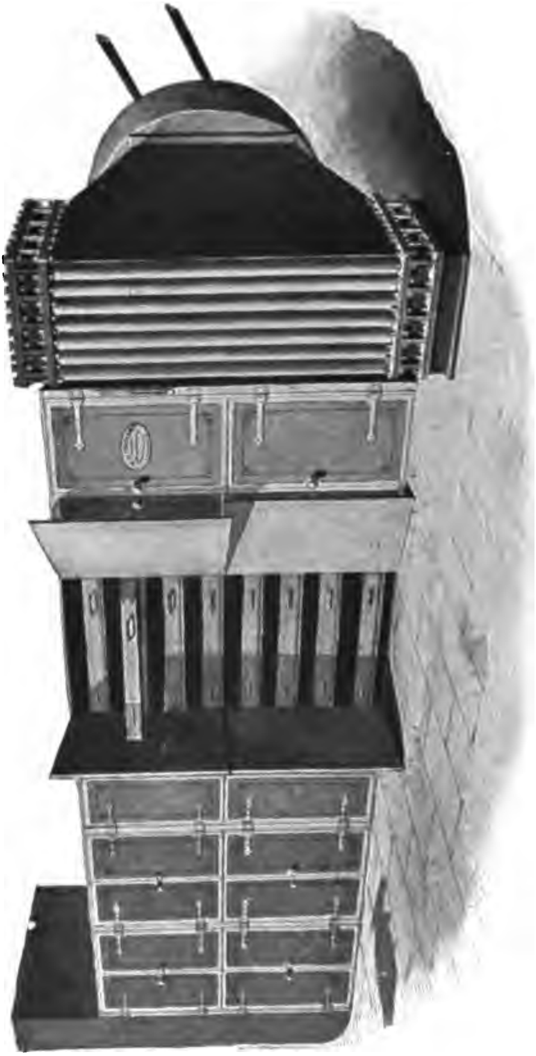


FIG. 153.—FRASER REMOVABLE TRAY DRYER. GENERAL VIEW.
(W. J. Fraser & Co., Ltd.)

air. In the casing B there are no steam pipes, as this allows the corn to cool down again, being further assisted by the cold air inlet and duct N.

The casings A and B are both kept full of corn by a supply, not shown, on to the automatic trays H, which are connected by the levers J to the outlet gates J^1, thus regulating the feed by the delivery.

By this simple gear, and without motive power, the corn is subjected to the heat of the steam pipes and the hot air, with ample divided exhaust, thus warming and thoroughly drying the corn, then subjecting it to a cold exhaust current to cool ready for storage. Exhaustion further cleans the wheat, and the fan discharges into a bin or a cyclone dust collector, not shown as it can be placed in any convenient position.

The floor space occupied is small, as a machine 3 ft. 3 in. by 3 ft. 9 in. will treat 80 bushels per hour, the height being about 28 ft.

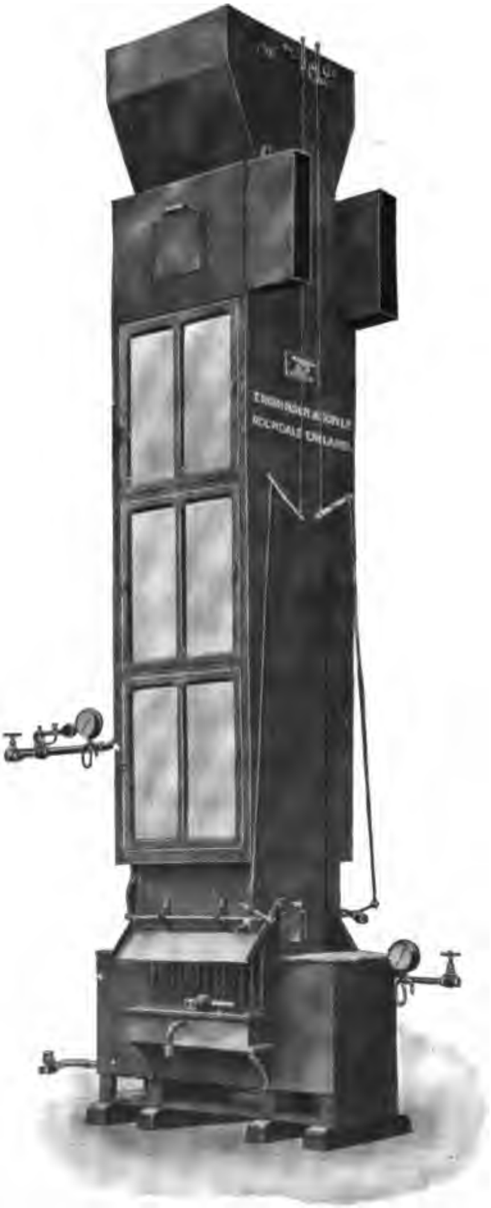
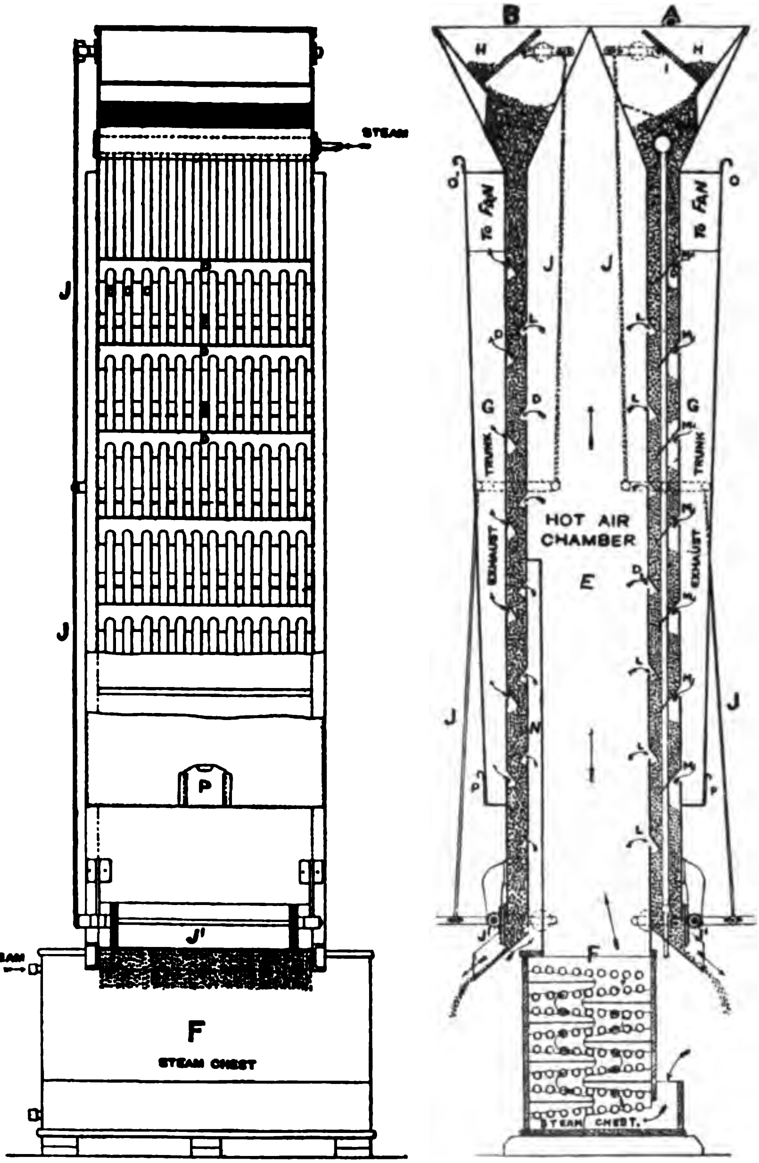


FIG. 154.—WHEAT DRYER AND CONDITIONER (PATENT). GENERAL VIEW.
(T. Robinson & Son, Ltd.)



A.—ELEVATION.

B.—SECTIONAL ELEVATION.

FIG. 155.—WHEAT DRYER AND CONDITIONER (PATENT).

(T. Robinson & Son, Ltd.)

The *Sturtevant Sliding-Panel Oven Dryer*, shown in Fig. 156, is a compact installation worked by steam-heated hot air under fan pressure, having withdrawal section panels for exposing the goods.

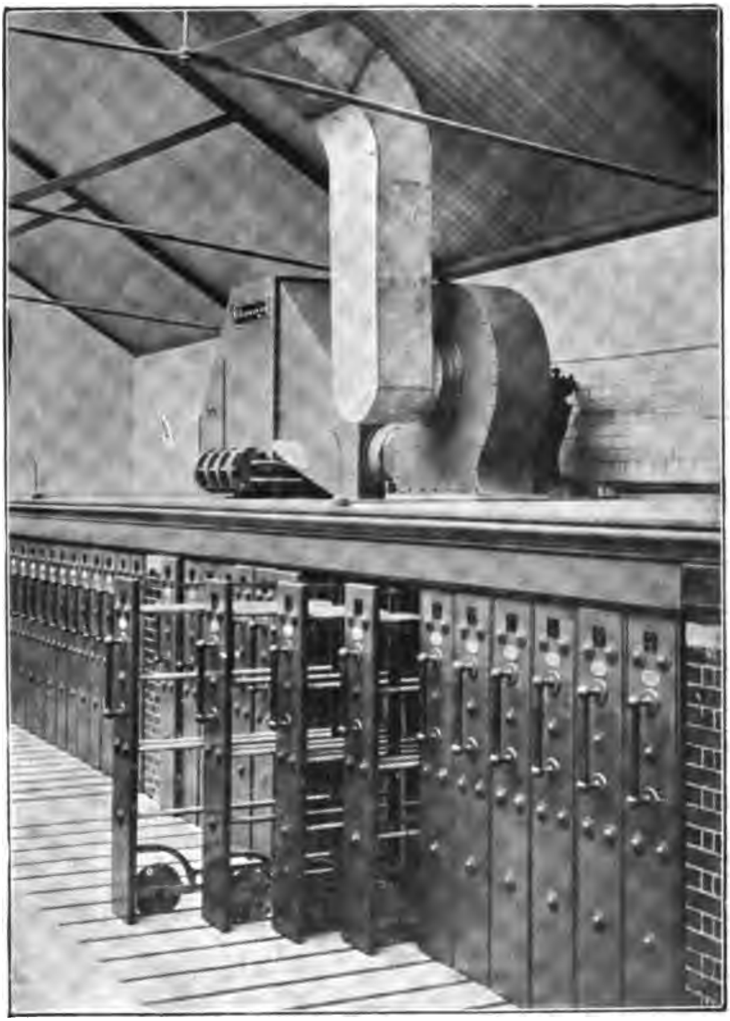


FIG. 156.—SLIDING-PANEL OVEN DRYER.
(Sturtevant Engineering Co., Ltd.)

The steam heater, fan, ducts, and connections are of the kind described on page 87 (Fig. 41). The hot air blast is applied from above, and passing through the goods is, after absorbing its burden of moisture, blown into the open.

The slide panels are built up with the hanging rods to form rigid horses for the goods, and are readily movable on the runner wheels and track. Each panel, being independent of the others, can be drawn singly if required, and with the minimum loss of heat, as the back closes the outlet, thus resealing the oven. This design is for laundry use, but can readily be adapted for yarns, piece goods, &c.

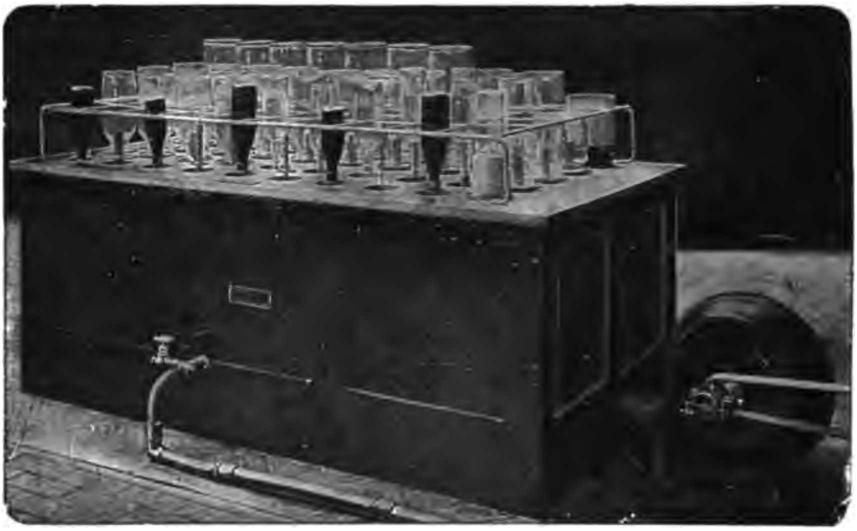


FIG. 157.—BOTTLE AND JAR DRYER.
(Sutcliffe Ventilating and Drying Co., Ltd.)

The *Sutcliffe Bottle Dryer*, as illustrated in Fig. 157, is a machine for drying the insides of bottles, tins, jars, &c., and incidentally the outsides. The air, heated by steam radiator coil under the stand, is blown into a receptacle. This receptacle has a separate pipe or tap standing up in each bottle space. As the article is placed over the pipe, the heated air soon warms the article and expels all water in the form of vapour.

The economy of time and labour are considerable, especially when the dryer is placed adjacent to the washer.

Scott's Stationary Vacuum Oven (Fig. 158) dries without the air medium, working with a vacuum in the drying receptacle. Beside the oven (receptacle), the apparatus consists of a vacuum pump, a vapour condenser, and a water receiver. The oven is constructed of heavy cast-iron plates with strong ribs to resist the atmospheric pressure. The door and back are of plate steel, all the joints are machined to bolt together air-tight. The door is not hinged but runs on an overhead rail attached to the oven body. The door joint is hermetically sealed by a permanent rubber packing and swing bolts. The shelves are steam-heated grids all controlled by one valve at the back of the oven.

The vacuum pump is of the vertical dry type with mechanically moved valves, usually direct steam driven, and has substantial flywheel (see Fig. 64).

The vapour condenser is of the patent double flow type with solid drawn brass tubes. The water receiver is of steel plate with sight hole and water gauge fittings to allow of easy inspection while working.

In operating, the wet material is placed on nets or trays, which are then inserted between the heated grid shelves. When charged the door is closed and sealed, then the vacuum pump is started. As the vacuum increases the evaporation proceeds more rapidly at the temperature than it would do under atmospheric conditions, and the boiling point is lowered within the oven to a corresponding degree (see Table XI.). The abstracted vapour is cooled by the water circulated in the horizontal condenser, and as it condenses falls into the water receiver shown by the side of oven. So soon as the sight glass shows a stoppage of water deposit in the receiver the oven should be opened and emptied of the dried product. The period required varies with the nature and condition of the wet material, but in all cases the time saved is the great feature of the vacuum process. For the effective working of the plant, besides the apparatus mentioned there must be a steam supply for the pump, a good water circulation for the condenser, a steam trap for the exhaust steam from the grids, and the necessary steam and water pipes with valves, gauges, &c. The

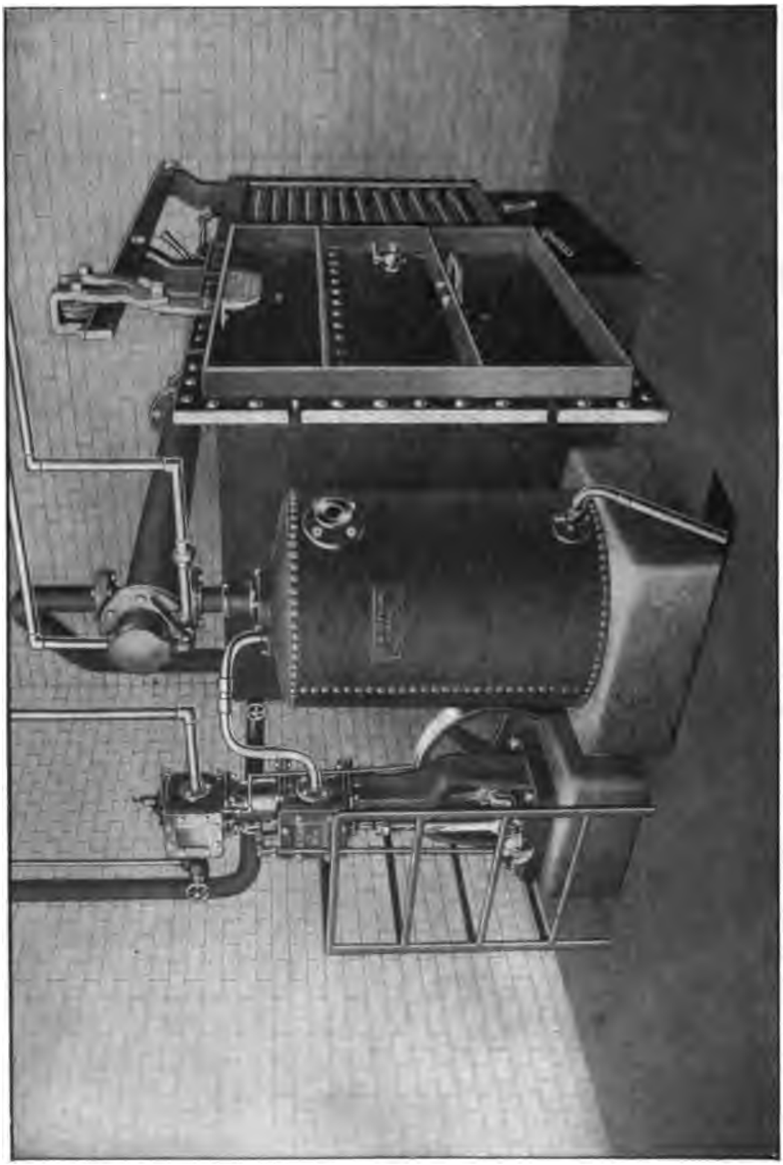


FIG. 158.—SCOTT'S STATIONARY VACUUM OVEN AND PLANT.
(G. Scott & Son, Ltd.)

ovens are made with standard size shelves more or less in number according to the output required.

The drying can be carried to any degree of desiccation with great economy of heat and saving in time if worked by experienced hands, according to the manufacturer's instructions for the particular material.

Fig. 159 is an elevation in part section of *Scott's Patent Vacuum Mixing Oven* designed for close-laying materials which need agitation or constant mixing during the drying process. The principle of working is the same as the vacuum oven described above (Fig. 158), but by the patent concentric opposite-handed spirals a rapid and intimate mixing is maintained in the charge. It is shown by the general view (Fig. 160), in the form for batch working of 1 cwt. to 30 tons per charge, but by the use of patent feeders and dischargers with a variation in the pitch of the interior spirals continuous working can be performed, the moist material entering at one end and leaving at the other end mixed and dried.

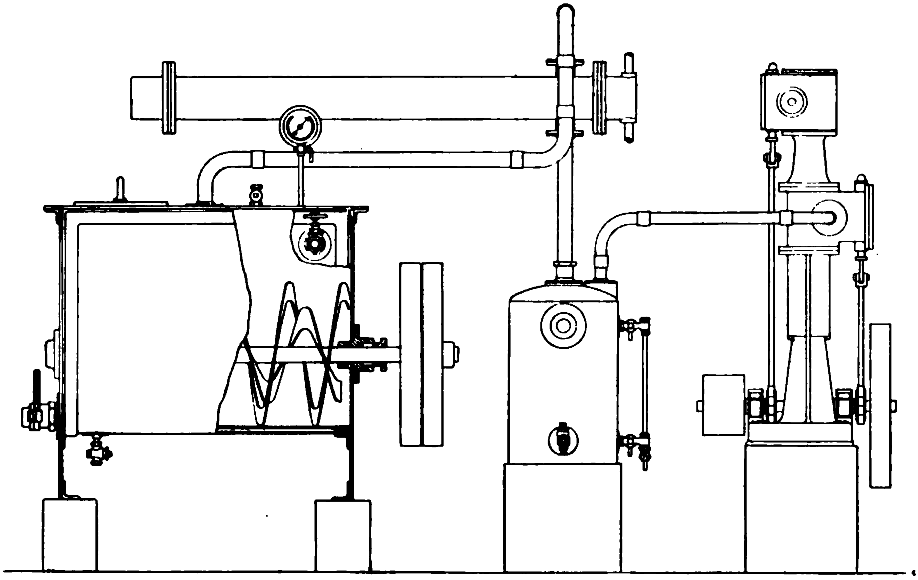


FIG. 159.—SCOTT'S (PATENT) VACUUM MIXING TROUGH AND PLANT. ELEVATION.

(G. Scott & Son, Ltd.)

Brewers' grains, malt, hops, fish, crystals, and powders which do not cake hard can be dealt with by this machine. Fig. 161 shows a series of five such working in battery.

Scott's Vacuum Continuous Oven (Fig. 162) is especially designed to continuously produce a dry powder direct from the liquid without intermediate handling. The auxiliary appliances are the same as for the previously described vacuum apparatus, that is the vacuum pump, the double flow horizontal condenser, and the water receiver together with the necessary pipes and valves.

The special feature is the oven or drying chamber which is of considerable length to contain a series of endless metallic bands supported and moved by driven rollers. The liquid is automatically spread over the metallic band at the receiving end, and as the band passes slowly along over and close to heated surface the liquid becomes dry by the time it reaches the delivery end. It is then automatically brushed off the band into a conveyor trough which discharges it out of the machine through a rotary valve outlet. Obviously by adjusting the heat and the speed of the bands the powder can be dried to any degree, and the feed and delivery being automatic there is no labour required save to attend to the mechanical operations of the machine. Hence the special applicability to food products and extracts which are preferably not to be handled. It will be noticed that each end of the drying chamber has a substantial steel crowned door to facilitate repairs, and these doors are carried on the runways similar to the stationary vacuum ovens (Fig. 158), while there are also smaller but strong inspection doors.

The *Padding Machine and Hot Flue*, shown by general view, Fig. 163, empty and without enclosure, also by the part sectional elevation, Fig. 164, illustrates a complete range of padding and drying apparatus. The fabric is taken from the feeding trolley, or stillage, passed through the padding machine, then over a series of guide rollers, between the steam-heated chests and through a hot air chamber or flue to delivery trolley. The whole traverse is mechanical and automatic at an adjustable speed to suit the fabric under treatment.

In the fore part of the chamber are a number of vertical flat steam plates placed at given distances apart and each having

FIG.

its own steam inlet and outlet. These subject the moving fabric to an even, radiant heat on both sides, producing regular vaporisation and oxidation. The "hot flue," besides being steam heated by a coil of steam pipes from below, has a hot blast. This hot air is introduced by pressure fan blowing through a multitubular heater into an air distributing trunk. This trunk discharges its current evenly between the individual

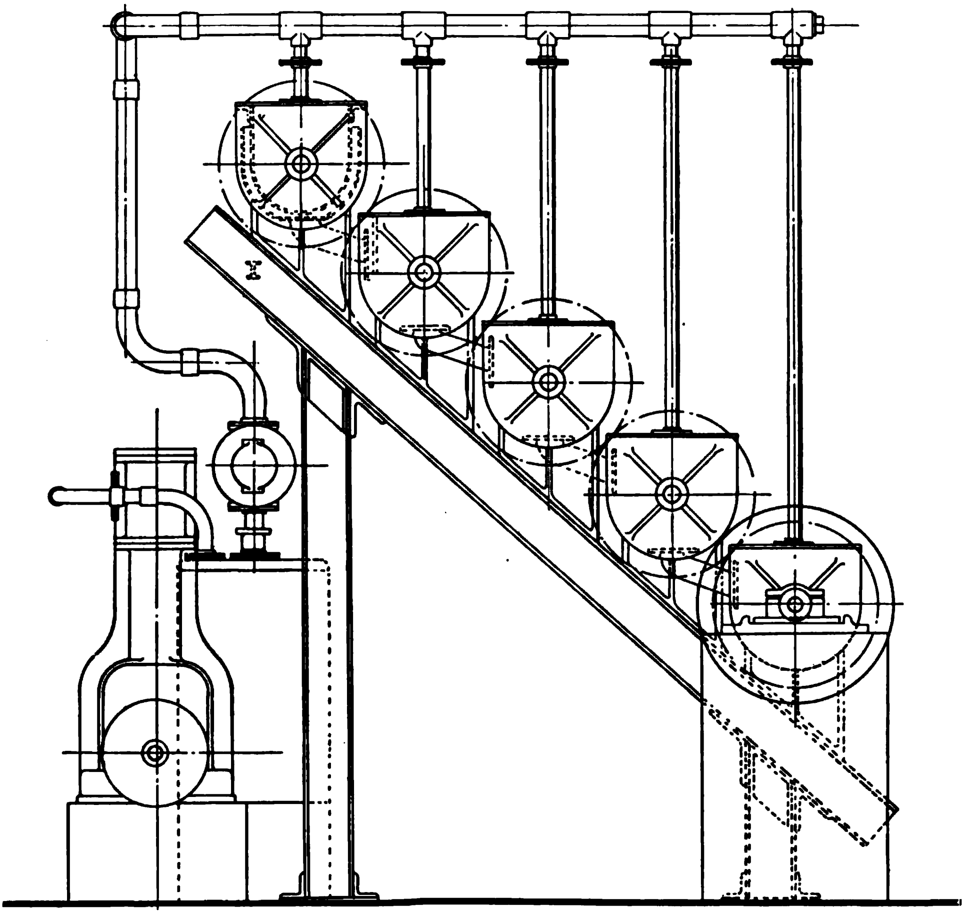


FIG. 161.—SCOTT'S (PATENT) VACUUM MIXING TROUGH. FIVE-TROUGH BATTERY. (G. Scott & Son, Ltd.)

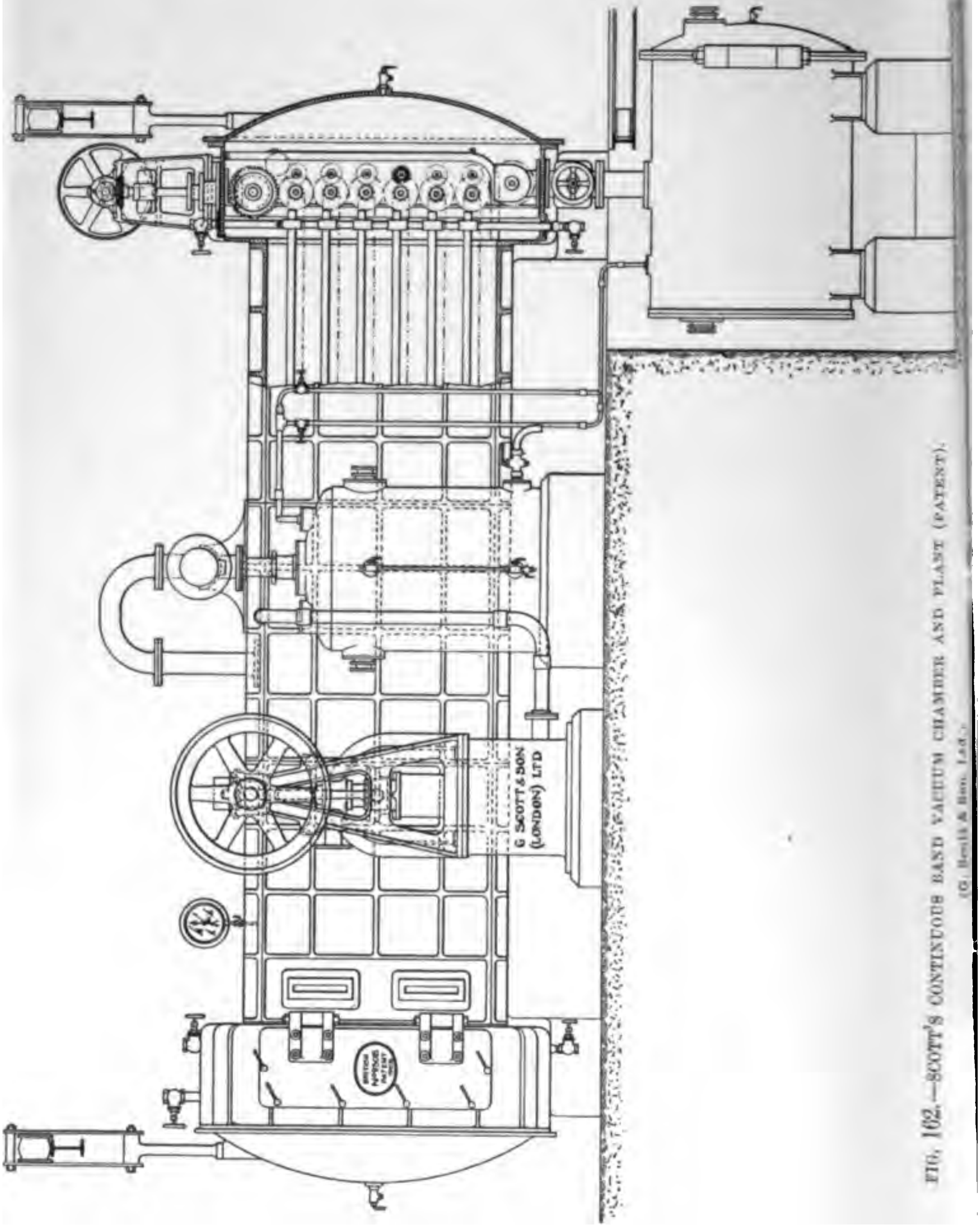


FIG. 162.—SCOTT'S CONTINUOUS BAND VACUUM CHAMBER AND PLANT (PATENT).

(G. Scott & Son, Ltd.)

folds of the fabric, ensuring rapid and equal evaporation and drying. The vapour laden air is assisted to evacuate by means of a suction duct and propeller exhauster.

The apparatus is carried on a steel framework built up of channels and bars of suitable section to obtain rigidity and stability, the whole being cased in with sheet-iron plates. While the whole room is enclosed the windows allow the entire length of the fabric to be inspected, and every part of the interior of the machine is accessible to the attendant.

The steam connections allow of a wide range of temperature and exact adjustment to the requirements from time to time. The relative position of the guide rollers, by avoiding long lengths of unsup-

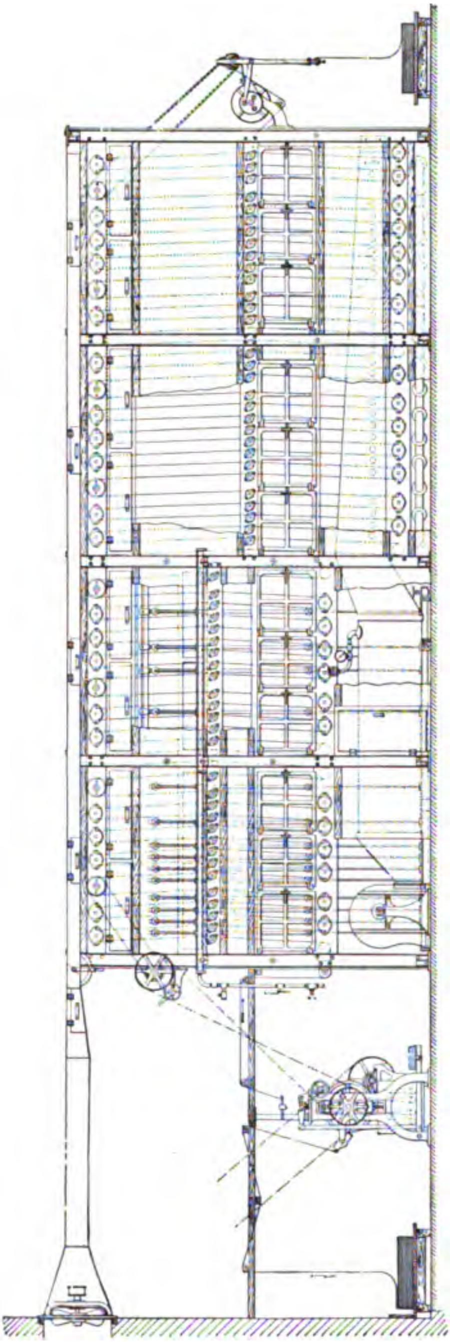


FIG. 164.—HOT FLUE ATTACHED TO PADDING MACHINE. ELEVATION PART IN SECTION.
(Mather & Platt, Ltd.)

ported cloth, prevents sagging, and allows of more rapid traverse through the room, without risk of creasing.

A *Drying-room for high-speed Printing Machines* is shown in Fig. 165, on somewhat similar lines to the preceding Figs. 163 and 164. In this type the printed fabric passes in close proximity to a number of steel steam chests (usually twenty) supplied with high-pressure steam. The drying chamber proper contains a large number of rollers round which the cloth is carried, making a continuous spiral until it passes over the large central driving roller. Up to this point only the unprinted side of the cloth has come in contact with the guide rollers, and it is so far dried as to avoid the danger of marking off or smearing of the colours, and the cloth can be allowed to return with its face to the rollers and between the laps of the entering spiral of cloth.

The apparatus is self-contained and enclosed in a steel casing. The framework is on similar lines to the padding machine and hot flue (Fig. 163), and either machine may be on the same floor with the padding machine, as in Fig. 164, or on the floor above, as in Fig. 165.

Desiccators.

Characteristics.—Desiccators are drying machines which carry the operation of drying to the degree of abstracting all the free or uncombined water, and frequently a goodly portion of the combined water when the water is combined with some volatile elements. Hence desiccators may be of any type of dryer which, working by evaporation, and working intensely, carry their usual operations to a more thorough degree.

The dangers inherent to the various dry products are naturally increased as the desiccation proceeds, and the machine needs designing in accordance, otherwise there is no essential difference from the usual types of kilns, stoves, cylinders, tunnels, rooms, and ovens previously described. In fact, in many cases the difficulty is to prevent desiccation in portions of the product, and in the direct-fired to avoid dehydration and calcination. There are many machines especially designed for desiccation, but they need no description apart from the drying machines of the same type.

Fig. 166, *Scott's Patent Continuous Desiccator*, is of the

vacuum type described under "Ovens," page 260, hence the auxiliary apparatus needs no further description. The desiccating chamber shown in vertical elevation and part section has

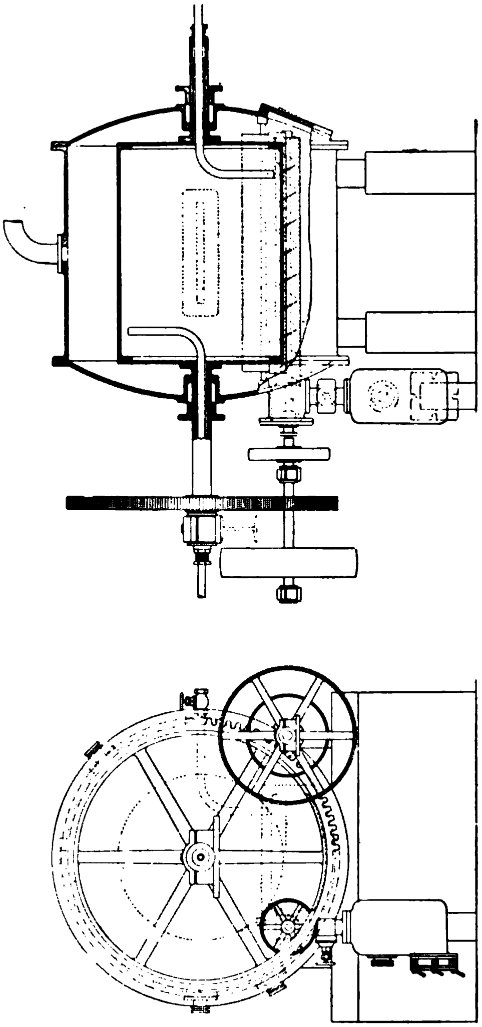


FIG. 166.—SCOTT'S (PATENT) CONTINUOUS DESICCATOR FOR LIQUIDS.
(G. Scott & Son, Ltd.)

some interesting mechanical features especially adapted for desiccating liquids and thin pastes.

The liquid is automatically fed into a tray contained in the outer air-exhausted casing by an adjustable suction device. The inner polished revolving drum dips into this tray, and is thus thinly coated by the liquid. This inner drum being heated by means of the steam inlet and outlet pipes shown in section through the trunnions, the coat of liquid rapidly dries on to the outer surface. The desiccating is accelerated and modified by the state of vacuum in the outer casing. When the coat is desiccated to the required degree, which is performed during one revolution of the drum, it is met by some removing knives, which cause it to fall into a small conveyor. This conveyor is also within the outer casing, and discharges the desiccated product as a fine perfectly dry powder by means of a patent rotary valve (see Fig. 77).

From the elevation the method of overcoming the difficulty of rotating points at the trunnions can be seen to be by adjustable glands, while the inner cylinder or drum and the discharge conveyor are shown as driven by spur gearing at the necessarily slow speeds. Speed-varying devices are usually fitted to accommodate requirements.

Being automatic in feed, operation, and discharge, no handling or other labour is needed, hence the suitability of this machine for treating milk and other food products.

Milne Twin Cylinder Desiccator (Fig. 167) has two cylinders of 28 in. diameter and 5 ft. long, which revolve in opposite directions from the centre downwards. The cylinders are sprayed at the centre with the milk or other liquid to be desiccated. The heat is by steam at 28 to 40 lb. per square inch to the interior of the cylinders. The liquid forms a film on the surface of the cylinders, and, becoming drier as they slowly revolve, is readily removed by the adjustable doctor knives shown near the top of the cylinders. The desiccated material falls into the receptacle at each side. The speed is about six to ten revolutions per minute by belt drive through the worm and wheel gear absorbing about 4 H.P.

Each cylinder has its own connections and steam trap for removing the condensed water, and a joint reducing valve for adjustment of the steam pressure. They require about 900 lb. of steam per hour at 40 lb. per square inch to evaporate the liquid from 70 gals. of milk, and leave a desiccated powder.

The machine is thus a self-contained complete apparatus for desiccating liquids to powders occupying only 8 ft. by 10 ft. with a large output without auxiliary appliances.

The *Boreas Portable Cable Desiccator,* as illustrated in Fig. 168, acts on the principle of injecting a current of dry compressed air into the cable which has to be desiccated. The trolley on four wheels is conveniently drawn by hand to the manhole of the cable, as the total weight of the plant is about 12 cwt.

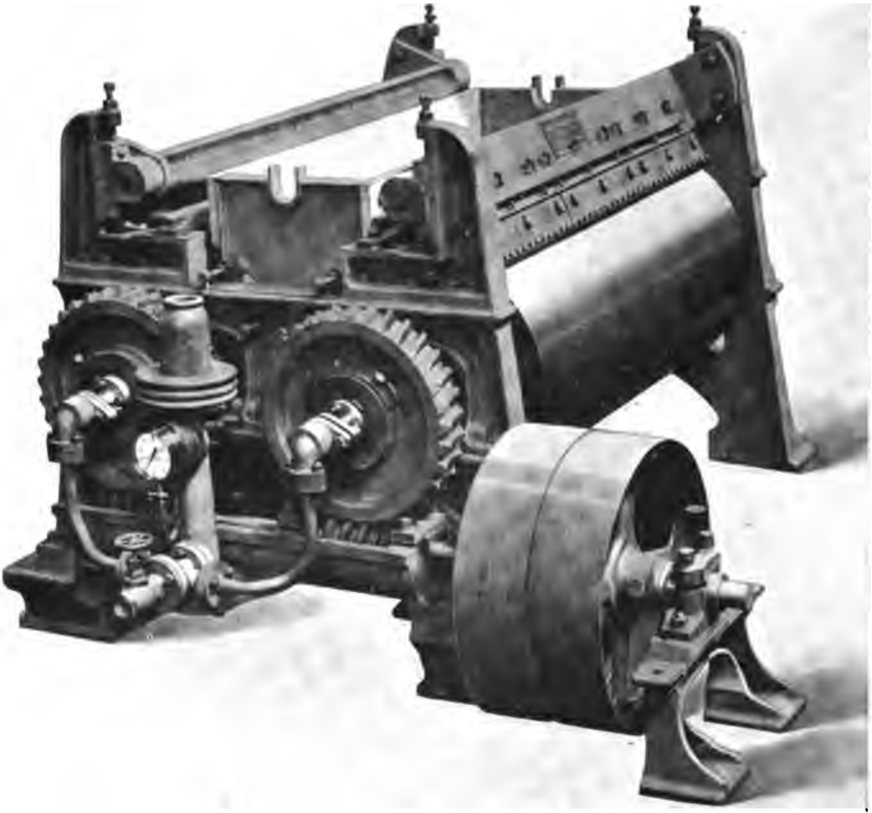


FIG. 167.—MILNE TWIN CYLINDER DESICCATOR. GENERAL VIEW.

(Jas. Milne & Son, Ltd.)

The apparatus consists essentially of an air compressor, an air receiver, desiccating cylinders and connections, besides the motive gear.

The Boreas patent air compressor shown in the centre of the trolley is in this case driven through gearing by an electric motor of about 1 H.P. The compressed air passes from the compressor, through an intermediate air receiver, where a certain cooling effect takes place, to the four desiccating cylinders, which contain calcium chloride for absorbing moisture from the air before it is forced into the cable. The usual working pressure of the plant is about 25 lb. per square inch at the compressor, but this may be increased to suit the length of cable, as the machine can work to 60 lb. per square inch.

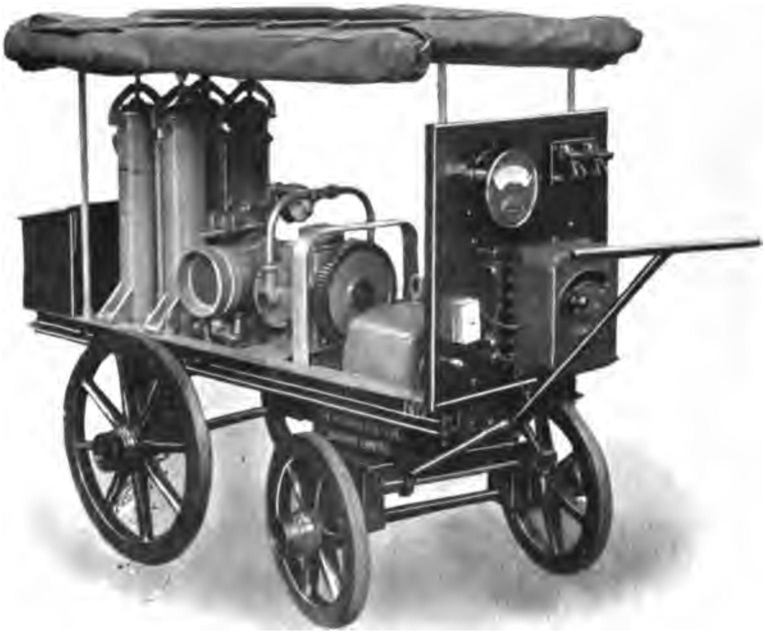


FIG. 168.—BOREAS PORTABLE CABLE DESICCATOR.
(Lacy-Hulbert & Co., Ltd.)

The mechanism is self-contained and complete with motor, starter, double pole fuse and switch, and ampere meter.

The plant includes a suitable tool box, hand tools, couplings, &c., while the carriage is surmounted by a light frame carrying a waterproof canopy to cover the gear. Although here shown as electrically driven, it can be fitted with oil or spirit engine when advisable.

The desiccating plant shown in Fig. 169 works on the vacuum principle by means of special vacuum pump vapour condenser and water receiver. The drying or desiccating chamber has steam-heated trays superimposed one over the other. At each end of each tray there is a roller and over each pair of rollers is a continuous phosphor bronze band. The rollers are driven by worm and wheel gearing inside the machine and belt pulley on the outside with step cone to allow

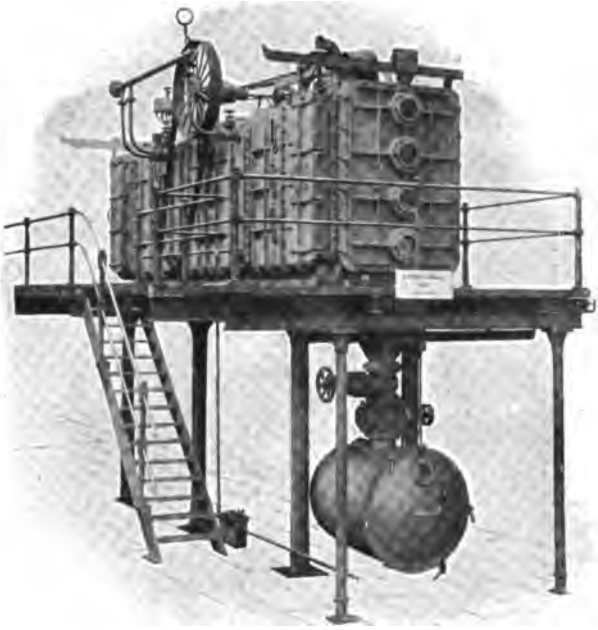


FIG. 169.—BLAIR'S (PATENT) CONTINUOUS-WORKING VACUUM DESICCATOR.

(Blair, Campbell, & M'Lean, Ltd.)

of varying speeds. The process of working is as follows:—The access doors are closed, the steam turned on in the trays, and the vacuum pump exhausts the chamber. The rollers are then started and they cause a continuous traverse of the phosphor bronze bands.

The material (liquid) to be treated is conveyed into the chamber at one end by means of pipes with cocks, and then deposited or sprayed in a thin layer on each separate band. As each band travels along over the steam-heated trays its layer of liquid is progressively dried, and by the time the material reaches the other end of the chamber it can be desiccated to any required degree by varying the speed of traverse. When the metallic band turns round the far roller the dried product falls off into the delivery hopper beneath.

There is thus a continuous feed and progressive drying with an automatic continuous discharge of the dried product into the delivery hopper, which can be emptied when requisite by shutting off the valve between the receiver and the chamber.

The time in traverse of the bands varies from ten to twenty minutes according to the character of the material and the degree of drying or desiccation desired. There are windows or sight holes at the ends and sides of the chamber to allow of inspection throughout the traverse, while the feed can be regulated by means of the feed valves.

Autoclaves.

Characteristics.—Autoclaves are not necessarily drying apparatus, being essentially self-fastening vessels to contain material while it is being subjected to pressure or vacuum. Many autoclaves are used as digesters for bones, meats, &c., but when used in connection with other operations, they frequently dry the material preparatory to further manipulation. For instance, timber is thoroughly desiccated in steam-heated autoclaves working under a vacuum, and when the entire mass has its pores completely emptied of sap and moisture, the vacuum is shut off. Then special impregnating mixtures are introduced to the autoclaves under pressure, the natural result being the complete impregnation throughout all parts of the timber to a degree which would be impossible without the previous desiccation. Then in the case of hardening of *sand-lime bricks in autoclaves*, as delivered to the autoclave on the trucks shown in Fig. 170, the bricks are simply mixtures of sand, lime and water held together as the result of the pressure they have undergone in a special brick press. If allowed to dry by exposure, no combination of these ingredients would take place. But by placing in an autoclave and subjecting to a temperature of about 300° Fahr., while the water is intimately distributed throughout the mixture, chemical action is induced and the ingredients combine to form an insoluble silicate of lime. The combination of the several ingredients could not take place in a dry heat, but at the same time it dries the bricks to a considerable degree.

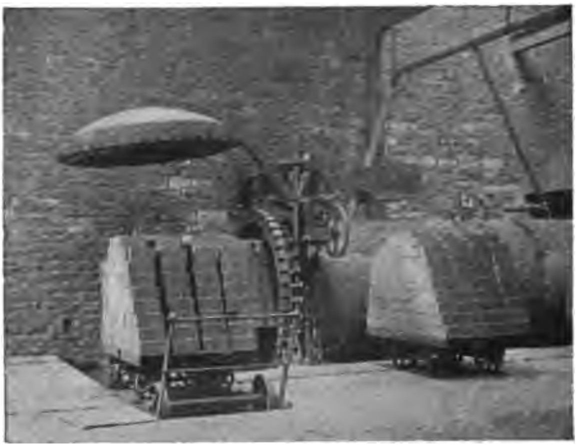


FIG. 170.—SAND-LIME BRICK AUTOCLAVE.
(Sutcliffe, Speakman, & Co., Ltd.)

From the illustration the nature of the door is well seen. These doors are dished to stand the pressure of about 120 lb. per square inch, and strengthened by the joint ring adapted for swing bolts. The hinge and spur sextant are worked by a hand-wheel and balanced by a weight to facilitate the movements. The cylinder, constructed of $\frac{5}{8}$-in. steel plate, is 6 ft. diameter, and about 30 ft. long, varying according to output. The shield, the end of which just shows in the print, prevents the condensation water injuring the bricks, as the drip is considerable, and may injure 5 per cent. or more of the output. The process lasts eight to ten hours, during which about 120 lb. steam pressure is maintained, and the cylinder cools down considerably. The admission of a new supply further reduces the temperature with consequent contraction in the cylinder, hence the necessity of ample provision in the material and erection of these autoclaves, for the constant changes.

Fig. 171 shows a type of autoclave used for disinfecting under the *Delépine-Jones patent* by *current pressure* steam, the articles being thoroughly dried while remaining in the autoclave. The machine consists of an outer steel shell lined with a continuous close coil of steam piping. Pressure steam passes from the boiler through this coil into the disinfecting chamber by a perforated pipe which lies at the bottom of the coil. The perforations are so arranged that the steam entering the chamber impinges on the coil. Superheating is impossible, as

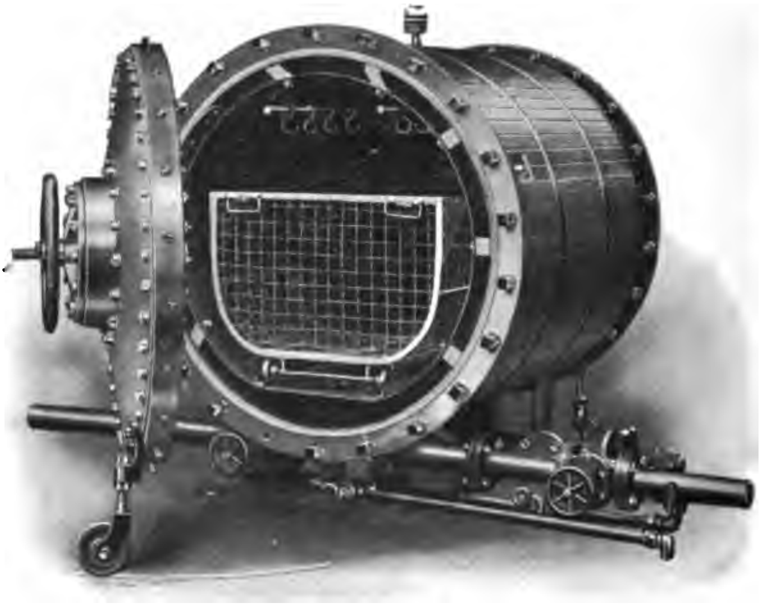


FIG. 171.—DELÉPINE-JONES AUTOCLAVE (PATENT).
(Thresh Disinfector Co., Ltd.)

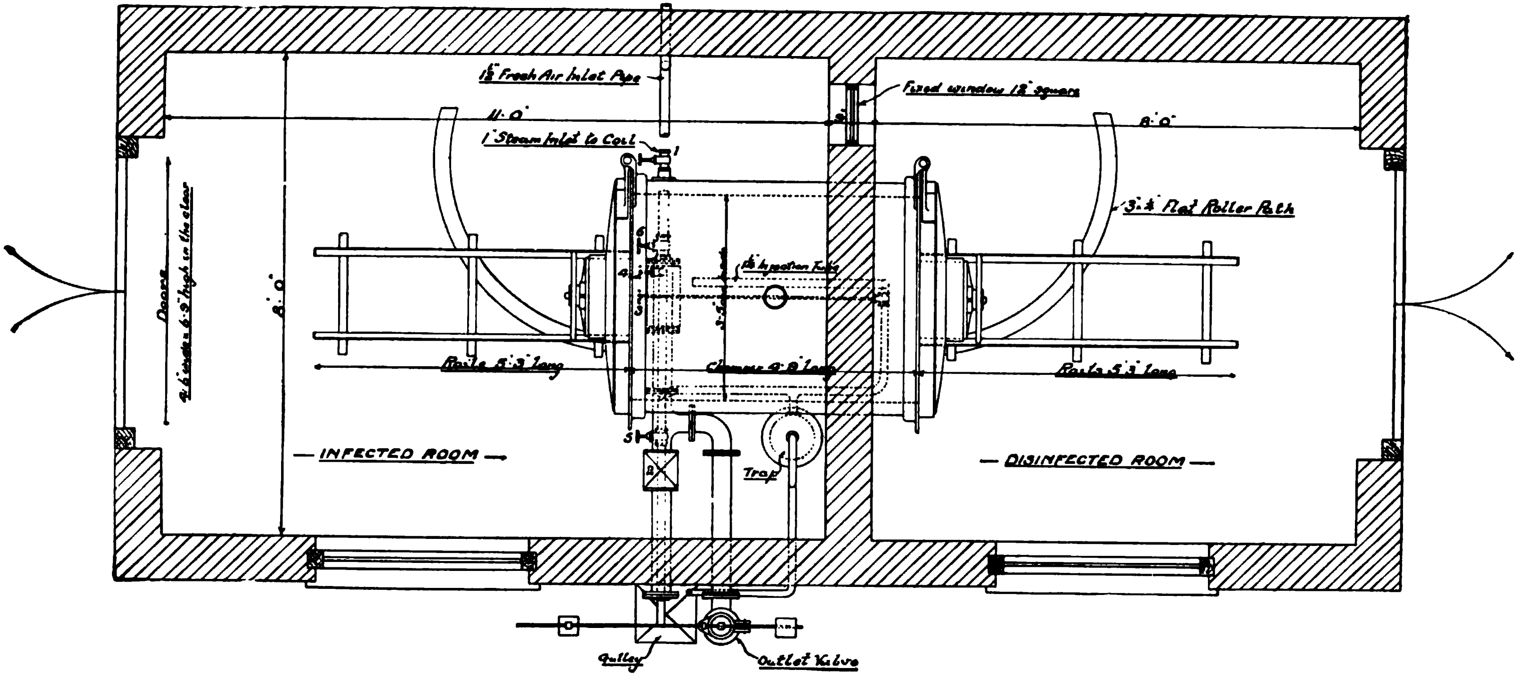
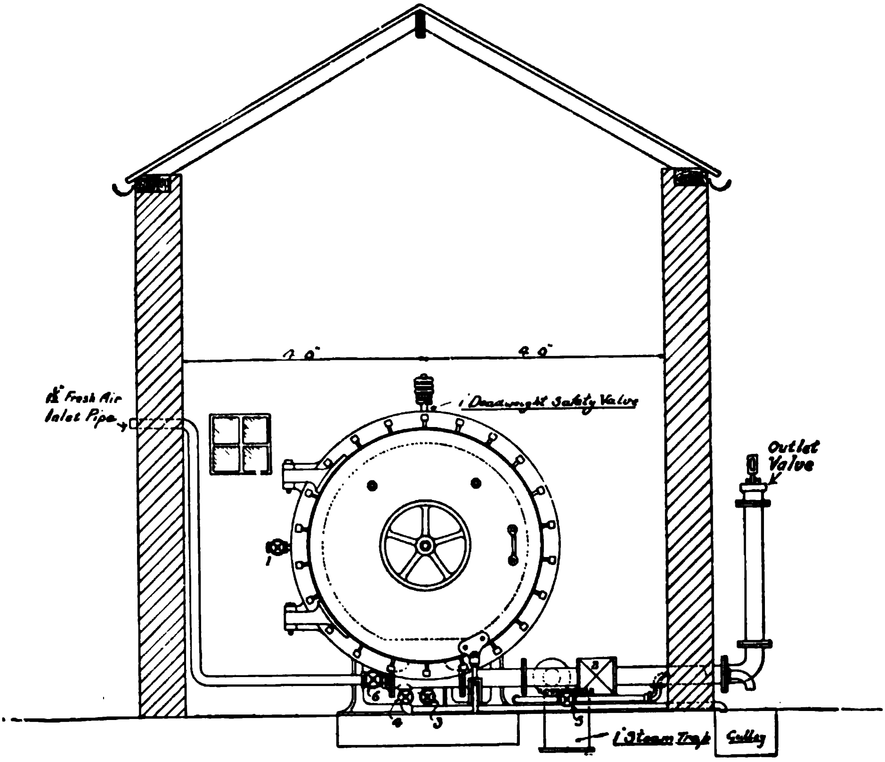


FIG. 172.—DELÉPINE-JONES DISINFECTING HOUSE. PLAN.
(Thresh Disinfector Co., Ltd.)

the steam condensed upon entering the chamber is rapidly re-evaporated and remains saturated. The inner lining causes the air, which, when drying, is admitted at one end of the machine, to travel over the coil containing the pressure steam before it obtains access to the disinfecting chamber.



Mark	Index to Valves
Nº1	Steam Inlet to Coil in Jacket
· 2	Steam + Air Outlet Pipe
· 3	Steam Inlet to Chamber
· 4	Drain from Jacket
· 5	Steam Jet to Steam + Air Outlet Pipe
· 6	Fresh Air Inlet

FIG. 173.—DELÉPINE-JONES DISINFECTING HOUSE. ELEVATION.
(Thresh Disinfector Co., Ltd.)

The steam for working the disinfector may be of any initial pressure, and disinfection is arranged at any pressure required up to 20 lb., according to the nature of the work to be done, and is regulated by an adjustable safety valve.

The doors are fastened or unfastened by a hand-wheel, thus dispensing with bolts and clamps, besides saving time, while the pressure assists in making tight the joints.

The process consists of placing the articles in the basket or on the hooks from the receiving (or infected) end, closing the door and putting on steam at the proper pressure, and for the requisite time according to the work. Then shutting off the steam and opening the air inlet valve, a rapid current of hot air is drawn through the disinfecting chamber and the articles are thoroughly dried. The delivery (or disinfected) door is opened and the goods removed.

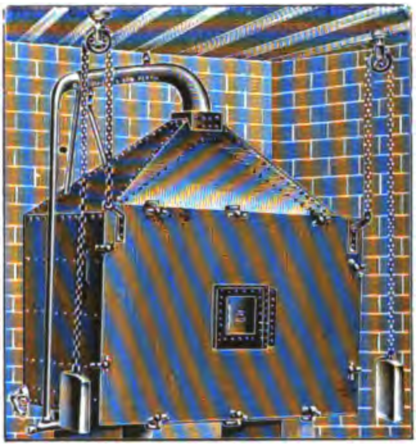


FIG. 174.—BENZINE RECOVERY DRYER.
(D. Gorrie & Son.)

Fig. 172 gives the plan of a suitable building for working one of the disinfectors expeditiously and efficiently. Fig. 173 gives an elevation of the same installation. The arrangement is clearly one to safeguard the goods from reinfection, while the working of the machine has stood all the bacteriological tests.

In drying articles which have been washed or manipulated in volatile oils or methylated spirits, it is advisable and economical to use a stove which is sealed up similar to an autoclave. The *Evaporating or Drying Stove* illustrated in Fig. 174 is such a stove as adopted to the hat trade, also dyeing and dry cleaning works.

These stoves are built in copper, steel plate, or tinned steel plate, according to the nature of the liquor and purpose, while the size will be according to the kind of article and the method of handling same.

The sealing of the door by claw bolts and the counterbalancing to facilitate opening and closing, as well as the tapering connection for exhaustion, are shown on the illustration. The internal arrangement, whether of racks, shelves, hooks, or trucks, varies according to the article to be treated. The diminished risk of thus drying is apparent, while the vapours are condensed and purified for re-use.

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GLOSSARY OF TERMS

In order to simplify and make more explicit the descriptions it will be advisable to get a clear understanding of the terms used. The terms are used very loosely in the ordinary course of trade, and in the catalogues of heating and drying machinery which form the main literature on this subject. In fact, such catalogues form the only literature which is at all likely to pass into the hands of users. The absence of any previous book or recognised authority tends to produce and perpetuate this unfortunate tendency, thus making it the more necessary to define the terms as used in this book.

It must be clearly understood that while the best known practice is followed in each case, the explanations will not always agree with preconceived notions or common usage. The terms are here defined as used in their technical sense, as applied to this branch of engineering and as used in this book, hence they will not in every case have the same meaning attached to them as given in the best standard general dictionaries. In some cases terms have purposely been defined to more distinctly mark a difference which is often ignored or confounded, *e.g.*, stove, oven, furnace, kiln.

Further, as this book is intended for those who want to learn about drying, it has not been thought advisable to omit explanation of the simple terms which all engineers are supposed to know, but may not remember their exact significance in relation to drying. For the same reason some terms are defined which are literally connected with drying terminology, but have no direct connection with drying practice.

Many of the terms are not explained in the body of the book, although repeatedly used. The references and cross-references should be carefully made in order to realise the full significance of the definitions.

Absolute Moisture	is measured by the weight of water actually present in the form of vapour in the unit of volume (*cf.* Humidity, and see page 8).
Absolute Pressure	of steam is the pressure above vacuum and is generally expressed by the amount either per square inch in lb. or in inches of mercury. By the Metric System kilos and millimetres replace lb. and inches. See Diagram I., and page 60.
Accidental Water	is the water present in a material which is not necessarily present for its then state. For instance, "dried fruits" may be thoroughly wet after they have been "dried" (*cf.* Dry Wood).
Aeration.	The circulation of air by natural means and at atmospheric pressures as distinguished from air currents produced mechanically by propeller, fan, or blower.
Ageing Machine or Ager	is a gradual drying machine for piece goods by prolonged exposure to moderately warm air currents.
Air Conditioner.	An apparatus for dehumidifying the air by condensation (refrigeration), chiefly used for air required dry at low temperatures and for blast furnace practice.
Air Dry or Air-dried	is a term applied to materials which have been dried by currents of air without any artificial heat. Many materials are so preferred although mainly because the application of heat without an increased air current tends to "cook" and "cake up" the pores, *e.g.*, chalk, leather, and explosives.
Air Meter	is an instrument for measuring the velocity of air flowing through a given passage or orifice. It consists of a light and delicately constructed fan wheel whose motion is transmitted by a system of gearing to a dial. See page 66.
Anemometer	is an instrument for measuring the force and the velocity of the wind. There are many forms suitable for differing conditions. See page 65.
Anhydrate.	To displace water, from a substance naturally containing it, by means of some other liquid, *e.g.*, glycerin and alcohol are used to displace the water in animal matter, protoplasm, &c.
Anhydrous.	Without water in its composition, *e.g.*, anhydrous ammonia, quick-lime, plaster of Paris.
Artificial Drying	is the removal of water or moisture from solids or semi-solids under other than natural conditions. All drying is performed by natural means but the conditions of application vary greatly. Vacuum drying is the most artificial of the processes.

Atmospheres. See Atmospheric Pressure.

Atmospheric Pressure. The atmosphere encircles the earth with a layer some 50 to 100 miles in thickness. This heavy fluid mass exerts on the surface of all bodies a pressure entirely analogous both in nature and origin to that sustained by a body wholly immersed in a liquid. At sea level this pressure is equal to 14·7 lb. to the square inch of surface, say roughly 15 lb. A gas or liquid which acts in such a manner that a square inch of surface is exposed to a pressure of 15 lb. is called a pressure of *one atmosphere*. If for instance the elastic force or tension of the steam of a boiler is so great that each square inch of the internal surface is exposed to a pressure of 90 lb. (= 6 × 15), we say it is under a pressure of six atmospheres. This atmospheric pressure is measured by barometers of which there are various types. One atmosphere equals 760 mm. (29·921 in.) pressure of mercury.

Atmospheric Process of Drying is the plan of drying by air at the ordinary pressure of the atmosphere without any mechanical assistance to increase the draught. See Aeration.

Atom. An atom is the smallest portion of an element which can exist in the molecule of any one of its compounds (*cf.* Molecule).

Atomiser. An apparatus to reduce liquid to spray (*cf.* Vaporiser).

Autoclaves (Auto-clavis) are self-fastening vessels in which timber, sand, lime, bricks, and other materials are subjected to heat by steam or hot air under pressure. Sometimes they are exhausted of air preliminary to applying the pressure. Used for desiccating, impregnating, digesting, sterilising, disinfecting, and assisting steam action. They usually consist of stationary cylindrical vessels with domed ends constructed of iron or steel, and provided with a removable cover so constructed that the pressure increases the tightness of the joint. Sometimes live steam or other vapours are injected, sometimes they are steam jacketed. They always need a suitable safety valve.

Board of Trade Unit (B.T.U.) is the unit of electrical energy as stipulated by the Board of Trade, and equals 1,000 Watt-hours, or 1⅓ horse-power per hour (746 Watts equal 1 horse-power of electrical energy).

Boiling or Ebullition. A liquid is in ebullition (or boils) when it gives off vapour of the same pressure as the atmosphere above it. Hence boiling point will vary as does the pressure and the character of the liquid. Boiling is the rapid production of vapour in the mass of a liquid itself (*cf.* Evaporation).

Brat or Brattice is cloth or canvas used on endless conveyors when of an open nature to allow the drainage or aeration of the material (see page 154). As this cloth forms the travelling surface of the conveyor, the term "brat" is (in Lancashire) sometimes applied to the travelling surface whether of cloth or not.

British Thermal Unit (B.Th.U.) or the British unit of heat is the quantity of heat necessary to raise the temperature of 1 lb. of pure water by 1° Fahr. at 39·1° Fahr. (*cf.* Calorie).

Note.—One B.Th.U. = 0·252 calorie.
„ horse-power = 2,565 B.Th.U. per hour.
„ B.Th.U. = 772 ft.-lb.

B.Th.U. See British Thermal Unit (for Heat).

B.T.U. See Board of Trade Unit (for Electrical Energy).

C. or **Centigrade** is used to denote degrees of temperature as shown on the scale devised by Celsius for use with thermometers. Dividing the quantity of heat used in raising pure water just melted from ice to water just commencing to boil into 100 parts or grades, it is called the Centigrade (*cf.* Fahrenheit).

Calcining. Reducing to a calc or powder by the action of heat alone (*cf.* Roasting).

Calender (a corruption of Cylinder). A machine for smoothing and dressing cloth or paper by passing over one or more cylinders generally during the operation of drying. See page 198.

Calorie. The French thermal unit is the quantity of heat necessary to raise the temperature of 1 kilogram of pure water by 1° Cent. at 0° Cent. (*cf.* B.Th.U.).

Note.—One calorie = 3·968 B.Th.U.

Calorifier. Heaters are sometimes so-called from the French *calorifère.*

Calorimetry is the measurement of the *quantity* of heat. The quantity of thermal energy is usually defined by the extent to which it raises a known weight of a known substance at a known temperature. The unit chosen is called the Thermal Unit. The British Thermal Unit is the quantity which raises 1 lb. of pure water at 39·1° Fahr. through 1° Fahr., and its mechanical equivalent is 772 ft.-lb. Thermal quantities are measured by calorimeters.

Capillarity or **Capillary Attraction** is the form of molecular attraction or repulsion which acts when fine tubes are partly inserted in a fluid, *e.g.*, the oil in a lamp wick. See page 24.

Centrifugal Force is that natural force by which bodies rapidly revolving about a centre have a tendency to fly off at a tangent from the circumference of its carrier. The force which impels a revolving body away from the centre of its orbit. The faster the velocity the greater the centrifugal force, and the more readily the revolving body is impelled away from the centre. See page 36.

Centrifugals are machines utilising Nature's force which impels a revolving body away from the centre of its orbit. Here used as applied to those machines used to separate solids from liquids, but it is also in connection with centrifugal pumps, centrifugal disintegrators, centrifugal screens, centrifugal separators, and centrifugal fans. In each class of machine the rotary motion of some portion causes the material to revolve about the axis of that part, and to receive a centrifugal tendency utilised for drying, separating, screening, disintegrating, pumping, and blowing respectively.

Checking, as applied to lumber drying, is the undue closing up of the pores by the hardening of the albumen and resins in the sap before the watery constituents have been abstracted. These hardened constituents expand with the increasing temperature, and cause cracks in the timber.

Coefficient of Expansion is the factor or multiplier representing the amount of increase in the volume of a given substance on a rise of temperature of 1°.

For fixed gases—Fahr. $^\circ = \frac{1}{490} = {\cdot}00204$.
Cent. $^\circ = \frac{1}{273} = {\cdot}00366$.

Formula.—To find the volume of air or any fixed gas after an increase of temperature.

$$V_2 = V_1 + V_1({\cdot}00204 \times (T_2 - T_1)) = V(1 + {\cdot}00204 \times (T_2 - T_1)).$$

Where V_1 = Volume at original temperature,
V_2 = Volume at increased temperature,
T_1 = Temperature original in Fahr. °,
T_2 = Increased temperature in Fahr. °.

Coefficient of Transmission is the factor or multiplier for calculating the loss of heat in B.Th.U. per hour for 1° of difference in temperature between the two sides of the material through which the heat is transmitted. See Table XVI.

Conditioner is applied to a variety of apparatus to obtain uniformity of condition as to the percentage of moisture. See Humidifier and Air Conditioner.

Condition Gauge is an indicator of relative condition as to moisture by variation in weight of the same volume. See Gravimeter, page 6.

Conditioning Oven. An apparatus used to obtain a definite degree of dryness in samples so that they may be tested in a uniform state for an accurate comparison.

Conduction. The distribution or passage of heat, electricity, &c., through matter by its transfer from particle to particle (*cf.* Convection).

Convection is the distribution of heat, electricity, &c., by the transfer of heated particles from place to place (*cf.* Conduction, Radiation).

Crusted Goods, partly tanned leather as it leaves the drying stoves, so called from its extreme hardness.

Cycloidal Blower. A blowing fan or machine in which the impellers are made in epi-cycloidal and hypo-cycloidal curves and rotate into each other.

Cylinder (Drying) is used in those cases when the drying portion of the apparatus is essentially a cylinder in order to allow of a rotary motion, not where the apparatus or part thereof is merely cylindrical, but stationary. See Chap. IX.

Damp, for the purpose of comparing the humidity of solids and semi-solids, is here used when the moisture is apparent without touching the substance. See Chap. I.

Decantation. The process allowing water with solids in suspension to pass through one or more tanks where the solids precipitate and the surplus water flows over and away. See page 16.

Dehydrated, for the purpose of comparing the humidity of solids and semi-solids, is here used when the water held in chemical combination has been removed. See Chap. I.

Dehydration is the removal of water from any compound containing it as a constituent. The removal of water as an element in the composition of a substance.

Deliquescent. Certain salts, when exposed to moist air, attract its moisture and liquefy in the water so attracted. Such salts are said to be *deliquescent* or *hygroscopic*, and to *deliquesce*. Such salts may be used to dry air or other gases. Chloride of calcium, potash, quicklime, carbonate of potash, sulphuric acid, zinc chloride, &c., have this property.

Desiccant (*n.*). A substance which tends to dry up other substances, generally by its own greater affinity for water.

Desiccate (*v*). To expel moisture from; especially to bring to a *thoroughly* dry state.

Desiccated, for the purpose of comparing the humidity of solids and semi-solids, is here used when all the free water which has been held as a chemical mixture has been abstracted. See Chap. I.

Desiccating. The act or process of depriving of moisture, especially the evaporation of the aqueous portion of a substance, as wood, meat, fruit, milk, &c., by artificial heat, as by a current of heated air.

Desiccation Cracks (Geology)	are the cracks or fissures caused by the desiccation or drying of the ground, generally arising from the outside (or surface) drying and shrinking more rapidly than the inside or lower layers.
Desiccatives (Medical).	Drying medicines.
Desiccator.	A machine or apparatus for drying something very thoroughly. It may be any type of dryer working to a high degree of dryness, practically abstracting all the water held as a chemical mixture, *i.e.*, uncombined.
Dewater.	Used in mining practice to denote the removal of the water and soluble constituents from the solid particles. See page 18.
Dew Point.	When a mixture of air and vapour is cooled down at constant pressure until the vapour is at saturation, the temperature at which saturation occurs is called the *dew point* of the original mass; and if the mixture be cooled below the dew point, some of the vapour will be condensed. See Humidity.
Distillation	is the process of heating in a vessel and condensing the vapour so formed. Generally the condensation of the vapour is the primary object, and is performed in a tube surrounded by cold water, communicating with another vessel called the receiver.
Draff (Distilling).	The refuse of malt which has been brewed from.
Draft Gauge	is for measuring low air pressures and vacuum, especially the draught in ducts, flues, and furnace uptakes. Usually it is of the syphon form, with graduated scale showing the aspiration of the air current in inches of water. See page 96.
Dried,	for the purpose of comparing the humidity of solids and semi-solids, is here used when *some* of the normal moisture has been abstracted. See Chap. I.
Driers (Painting)	are substances which hasten the oxidation of the oil and are usually added to paints. Some pigments have this quality, *e.g.*, white lead, red lead, lead chrome. The principal driers are sugar of lead, patent driers, litharge, sulphate of zinc, manganese borate, manganese acetate. See also Liquid Driers, Soluble Driers.
Drops.	The globules of water which drop in evaporating rooms when the air becomes saturated. See page 25.
Drosometer.	An instrument for measuring the amount of dew that collects on the surface of a body exposed to the open air during the night. It usually consists of a plate to receive the dew, balanced by a weight which is protected from the dew.

Drosophore.	An apparatus for maintaining the proper degree of humidity in weaving and spinning mills by a combination of atomisers and air currents. See Humidifiers.
Dry,	for the purpose of comparing the humidity of solids and semi-solids, is here used when the moisture is not apparent to the touch, but the mass contains the normal characteristic moisture of its composition. See Chap. I.
Dry (Cornish).	A "dry" is the local name in Cornwall for the drying floor of large fire-clay tiles, under which are a number of flues, used for drying china clay. See page 162.
Dry Air	denotes air whose humidity is zero. That is, there is no moisture in the same space. There is no "dry air" under natural conditions, although under extreme cold the amount of moisture in a given space may be so small as to be inappreciable. The characteristics given in weight, volume, elastic force, &c., are derived by assuming the entire absence of moisture.
Dry Air Blast (Smelting).	The air is dried by refrigeration before being heated and forced by flowing engines into the most modern blast furnaces, as it is found to increase the efficiency.
Dry-beat.	To inflict dry blows, to beat severely without drawing blood.
Dry Blower (Mining).	A portable machine for separating and sifting dry gold ore by means of shaking and an air current (*cf.* Dry-Washer).
Dry Bones	are those which have had their grease thoroughly removed, generally in an autoclave digester.
Dry Bottom (Smelting).	A puddling furnace is said to have a dry bottom when the slag is not allowed to accumulate, but is drawn off as frequently as possible.
Dry-cleaning.	Cleansing by naphthalene or other spirit solvent in the place of water.
Dry Coals.	The semi-anthracite coals of South Wales which burn readily with much flame and little smoke are known as "dry" or "steam coals."
Dry Compression (Refrigeration).	The system of compressing ammonia without the addition of liquid ammonia, the superheat of compression being removed by a water current in a condenser.
Dry Copper.	"Dry" is applied to copper which is unduly brittle in texture owing to faulty manipulation in its production.

Dry Distillation.	The destruction of a substance in a closed vessel and the collection of the volatile matters evolved. Thus illuminating gas is a product of the *dry* or destructive distillation of coal.
Dry Dock	A dock which can be emptied and kept dry for repair of ships, &c.
Dry Dyeing	is dyeing in a volatile spirit without water.
Dryer.	A contrivance or apparatus to remove moisture from solid bodies. See Filter, Filter Press, Vacuum Filter, Hydro-Extractor, Centrifugal, Floors, Gantries, Pans, Sheds, Kilns, Stoves, Cylinders, Tunnels, Rooms, Ovens, Desiccators, Auto-claves.
Dryer (Refrigeration).	A type of filter to take out any water from ammonia gas. It is generally charged with freshly unslaked burnt lime, and attached to the suction pipe of the ammonia compressor when in use.
Dryer-man.	A man who works some drying process or drying machine.
Dryery.	A drying establishment, including the buildings as well as the machinery and apparatus.
Dry-fat.	A vat or vessel to hold " dry " articles as distinguished from liquids.
Dry Felts.	The felting on drying cylinders used in paper-making, &c. See Chap. IX.
Dry Fining.	A process of polishing metals when a fine surface is required, subsequently to the ordinary polishing ; the article is finished upon a grained wheel dry, *i.e.*, without grease or paste.
Dry Fly (Fishing).	The " dry " fly is covered with grease or paraffin to prevent it getting wet so that it may float on the top of the water.
Dry-foot.	Without wetting the foot.
Dry-founder (Veterinary).	To render lame (horse) by inflammation of the foot.
Dry Fruits (Botany).	Fruits having a thin pericarp and little or no juice, as distinguished from "succulent" fruits which are more or less pulpy.
Dry Gas (Refrigeration).	Ammonia gas from which all water has been taken, *i.e.*, anhydrous ammonia.
Dry Goods.	Draperies, &c., as distinguished from groceries.
Dry Heat.	Heating by steam, but not allowing the steam to escape into the heated space.

Dry Horses.	The frames on which the goods are placed to dry. They are generally movable and interchangeable. Used in drying ovens or cabinets. See Chap. XI.
Drying	is the operation of separating some portion of the water from mixtures containing more or less solid constituents. See Soaked, Wet, Unwatered, Damp, Moist, Dry, Dried, Desiccated, Dehydrated.
Drying Oils.	Those oils which become *dry* and solid on exposure to the oxygen of the air, *e.g.*, linseed, hemp, poppy, almond, and colza.
Drying Press (Stereography).	A press with heated table for drying under pressure the moulds for stereotyping.
Drying Tower.	A tower used to dry the raw material of Portland cement before grinding.
Dry-kiln (American).	A timber drying oven or kiln.
Dry-lime Purification (Gas).	The process of using lime in a comparatively dry ("moist") state for gas purification as distinguished from using it in the semi-liquid state.
Dry Main (Gas)	is the second main or pipe from the retorts; it receives the gas partially dried by the deposits in the "Hydraulic" main.
Dry Measure.	The British unit of capacity for grain and dry materials is the Imperial bushel, which contains 2218·192 cub. in.
Dry Meter (Gas).	An instrument for measuring gas without any water seal.
Dry-moulding.	Moulding in sand which is afterwards dried before being used to cast. Used whenever castings are required of a superior quality from full patterns.
Dry Multures (Scotch).	Quantity of corn paid to a mill whether the payers grind or not.
Dryness Fraction (Steam).	Expresses the relation between the vapour and the liquid in steam during expansion in a steam engine cylinder. It can readily be calculated from the indicator diagram. The term has no direct connection with drying or desiccating.
Dry Picking (Paper).	The sorting of esparto before boiling in order to pick out the roots, dirt, &c. After boiling it is again sorted or wet picked.

Dry-pile (Electric). A number of discs of leather, paper, &c., coated on one side with an electro-negative and on the other with an electro-positive substance, which form a dry voltaic battery of limited power. Used for thermal indicating and laboratory purposes.

Dry Pipe (Steam). A collecting pipe in a boiler which is slotted or perforated to ensure dry steam.

Dry Plate (Photographic). Ready prepared sensitive plates which are dried and act on exposure without moistening.

Dry Point (Engraving). A form of mezzotint engraving in line. As the point of the stylus makes its scratch on the copper, it leaves a bur which retains the ink. Where the bur is removed remains dry, and gives the effect in printing.

Dry Pressed Bricks. Bricks compressed in the mould while in a dry state to obtain a superior finish, denser and better surface.

Dry Process (Cement). is that process of cement manufacture in which the "dry" materials are ground together to an impalpable powder or "flour," and subsequently mixed to correct chemical proportions.

Dry-puddling (Iron). The method of puddling in a reverberatory furnace where the metal is not allowed to pass beyond the pasty condition, as distinguished from pig-boiling, where the metal is in a molten state.

Dry Rent (Law). A rent reserved without clause of distress.

Dry Rolls (Paper). In paper manufacture hollow cylinders of copper, brass, and cast iron are heated internally by steam passing through their trunnions to dry the paper web as it passes the compressing rolls. See Chap. IX.

Dry-rot (Timber). A decay of timber caused by fungi which reduce to a *dry* brittle mass. The fungi develop most rapidly in a stagnant and moist atmosphere.

Drysalter. Originally a dealer in goods dried by salting, *e.g.*, dried meat, dried fish, &c. Now generally applied to a dealer in dry gums, dry dyes, dry drugs, &c.

Dry-sand. A moulder's term for a mixture of strong sands, coal dust, and dung used to form moulds which are dried by or in a stove before pouring in the metal. See Chap. IX.

Dry Scrubber (Gas). See Scrubber.

Dry Soap. A powdered soap made from a mixture of ordinary soap and soda crystals. The mixture dries on cooling, and can then be ground.

Dry Steam is saturated steam (*q.v.*).

Dry Walling (Mining).	Walls built up without mortar or cement in the joints.
Dry Washer (Mining).	A sifting and separating machine used in Australia to separate the gold ore from the gangue. In other parts usually called a Dry Blower (*q.v.*).
Dry Well (Gas)	is the well or pit for stand-pipe connections of a gasholder tank. For the convenience of working it contains no water.
Dry Wood.	Timber from which the sap has been removed either by seasoning or artificially. In other words it has the water incidental to its growth removed, but may be more or less wet with accidental water.
Duct.	A pipe or passage for leading air or vapour either by pressure or suction. If smoke or other products of combustion pass through, it is then called a flue or chimney.
Ebullition.	See Boiling.
Efflorescence.	Some salts lose the whole or part of their water of crystallisation in moderately dry air, even at ordinary temperatures, and are said to *effloresce*. The efflorescence arises from capillarity; the solution rising against the side of the vessel, the water evaporates, and the salt forms on the side a means of furthering still more the ascent of a liquid. See Chap. II.
Eliminator.	See Water Eliminator.
Equalising Chamber	is a closed chamber for allowing air to mingle to ensure an equal thermal condition at the outlet.
Evaporation.	Most liquids and some solids, when left to themselves in contact with the atmosphere, gradually pass into the state of vapour. The rate of this *evaporation* varies greatly with different materials, and is always accelerated by an increase of temperature. It occurs over a very wide range of temperatures, but there appears to be a temperature for each substance below which evaporation is insensible, if there be any at all. As compared with boiling, *evaporation* especially refers to the slow production of vapour at the free surface of a liquid (*cf.* Vaporisation).
Evaporometer.	An instrument for ascertaining the quantity of a fluid evaporated in a given time (*cf.* Vaporimeter).
Exhaust Process of Drying	is the plan of drying when the draught is assisted by propeller or fan withdrawing or exhausting the air, thus accelerating its velocity and lessening the pressure in the dryer. See Chap. VI.
Exsiccator	is a means of abstracting moisture, chiefly applied to paints, varnishes, &c.

Fahr. or **Fahrenheit** is used to denote degrees of temperature as shown on the scale devised by Fahrenheit for use with thermometers. The fixed points are regulated by the normal atmospheric pressure of 29·921 in. of mercury, when water solidifies at 32° Fahr. and water boils at 212° Fahr. (*cf.* Thermometer Scales).

Filter Press is an apparatus in which semi-solids and wet solids are subjected to pressing in order to extract the water or other liquid. Essentially it is built up of sections in which filtering is performed under pressure. See Chap. III.

Floor (Drying) is a floor adapted for drying purposes (in a more or less degree) and on which the material to be dried is placed. It may or may not be heated by flues. See Chap. VIII.

Flue. A pipe or passage for smoke and the products of combustion.

Foot-pound is the unit of work or energy, being one pound (avoirdupois) lifted one foot.

French or **Metric Units.**
1 metre = 39·37 in.
1 kilometre = 3280·869 ft.
1 sq. metre = 10·764 sq. ft.
1 sq. centimetre = ·155 sq. in.
1 cub. metre = 35·3166 cub. ft.
1 cub. centimetre = ·061 cub. in.
1 kilogramme = 2·2 lb.
1 litre = ·22 imp. gal.
1 kilogramme per sq. metre = ·205 lb. per sq. ft.
1 kilogramme per sq. centimetre = 14·22 lb. per sq. in.
1 calorie per kilogramme = 1·8 B.Th.U. per lb.
1 calorie = 3·968 B.Th.U.

Furnace. A structure in which to make and maintain a fire, the heat of which is to be used for some mechanical purpose. A combustion chamber.

Gantry (Drying). A framework of an open nature to support materials (or vessels containing materials) in a convenient manner for drying. It may or may not be in the open air, shed, room, or oven. See Chap. VIII.

Gassing (Textile). The process of singeing the hairy filaments of cotton and other textile fabrics. See page 156.

Gauge Pressure is pressure shown by the steam gauge, which indicates only the amount of the pressure in the vessel above the normal pressure of the atmosphere, so that it represents the difference of the pressures on the inside and outside of the steam vessel. In order to obtain the total pressure above vacuum of the steam, add 15 lb. to the gauge pressure.

Gravimeter is an indicator of varying weight of equal bulks of similar material. See Fig. 4.

Gravitation is the force by which all terrestrial bodies are drawn towards the centre of the earth. This causes all liquids to run downwards, hence to drain away. It causes all hanging particles to fall through liquids or gases, hence precipitate.

Heat, according to the best authorities, is not a substance but a *condition of matter*. By the theory of undulation the heat of a body is caused by an extremely rapid oscillating or vibratory motion of its molecules; and the hottest bodies are those in which the vibrations have the greatest velocity and greatest amplitude. The quantity of this molecular motion is measured in heat units (see B.Th.U.) by calorimeters. Owing to the different thermal capacities of different bodies the same quantity of units does not always produce the same intensity of heat, and so become *sensible heat* evident by thermometer or pyrometer as temperature. See Chap. IV.

Heaters. A term applied to nests of concentrated radiating surfaces. See Chap. V.

High Dried. A term applied to fish which have been dried throughout so that they will keep for long periods, for instance "red" herrings, as distinguished from those which are surface dried only to keep a short period, such as haddocks.

Hot Flue (Textile), applied to the enclosed space where drying is performed by a blast of hot air as distinguished from heating by radiation and exhausting the vapour. See Chap. XI.

Humidifier. An apparatus for increasing the humidity of the air and maintaining the humidity at a required degree. Especially requisite in textile working (*cf.* Vaporising Stove).

Humidity is the term applied to the condition of the atmosphere with relation to the amount of water which it holds in suspension as aqueous vapour. See Absolute Moisture, Relative Humidity, Saturation, and Chap. I. as applied to solid or semi-solid substances.

Humidors (American). A hygrometer of any practical form.

Hydraulic Main (Gas) is the primary main from the retorts, and besides acting as a self-acting seal valve and shut-off for the gas when the mouthpieces of the retorts are open, it also assists the deposit of the "wet" components of the gas before they enter the dry main (*q.v.*).

Hydrous. Containing water in combination.

Hydro-Extractors are centrifugal drying machines with the basket specially designed to handle textile fabrics and fibrous materials. The term is essentially more distinctive of its purpose than centrifugal, which term is equally applicable to machines utilised for altogether different processes, as pumping, screening, disintegrating, and pneumatic separating. See Chap. II.

Hygrodeik. A form of hygrometer with scale attached. See Fig. 1.

Hygrometers are instruments for measuring the hygrometric state of the air, that is its relative humidity, and there are many types. See Chap. I.

Hygroscopic Water is the amount of water which any material gives up or receives from exposure to the varying atmospheric conditions as to humidity. It varies with the condition, and each material's idiosyncrasies.

Incidental Water is the water essential to the maintenance of the state of a material. For instance, a dry apple contains a large percentage of moisture, incidental to its natural state. A "dry" apple still has a small amount of incidental water (*cf.* Accidental Water).

Incineration. The action or process of burning to ashes. To drive off by heat all volatile and combustible constituents of a substance.

J, or Joule, is the mechanical equivalent of heat.

Kiln (Drying). A building containing a furnace or combustion chamber, the direct heat of which is used for drying materials in the same chamber.

Latent Heat in a liquid is the quantity of heat which was required to convert a unit weight of its solid into a liquid at the same temperature. In a vapour *latent heat* is the quantity required to convert a unit weight of the liquid into a vapour at the same temperature. In each case it is the quantity which disappears at the moment of change and cannot be measured by the thermometer or pyrometer. This latent heat is again rendered *sensible* whenever the vapour or liquid respectively returns to the liquid or solid state.

Formula.—The latent heat of aqueous vapour may be found by

$$L_d = 966 - {\cdot}71(T_d^\circ - 212^\circ).$$

Where L_d = Latent heat.

T_d = Temp. of vapour.

Latent Heat of Liquefaction is the quantity of heat required to convert a solid into a liquid state at the same temperature. Thus 1 lb. of ice at 32° Fahr. requires 142·4 B.Th.U. to produce water at 32° Fahr. Water (1 lb.) emits 142·4 B.Th.U. on becoming ice. Therefore 142·4 is the latent heat of liquefaction for water; tin, 25·6 B.Th.U.; iron, 233·0 B.Th.U.

Relative Humidity of the atmosphere is the amount of moisture which it contains *as compared* with that of complete saturation at the given temperature and pressure as indicated by the hygrometer (see Humidity). This ratio is also called the hygrometric state or degree of saturation. See Chap. I.

Residual Moisture. The air of a drying chamber being hotter than the air outside has a greater capacity for water. Hence the air entangled with the goods removed from the drying chamber has a greater quantity of vapour than the outside air can carry, and this vapour causes the moist feel of the goods till it has dissipated into the air.

Retorrefying (Barley). The re-drying of barley, &c., by *hot* air currents, generally restricted to the mechanical application of the hot air, *e.g.*, in a rotary kiln.

Revolving is a movement of a body about a centre outside of itself (*cf.* Rotating, Rolling).

Roasting. The application of heat at a temperature below the melting point of the ore where a chemical change is involved resulting in the addition of an element (*cf.* Calcining).

Rolling. A body is said to roll when successive portions of its surface continuously touch successive portions of another surface, *e.g.*, two friction pulleys, belt on pulley (*cf.* Rotating, Revolving).

Room (Drying) is an enclosed chamber adapted to or used for drying into which it is necessary to enter in order to charge or discharge (*cf.* Oven).

Rotary (adj.). Moving about one's own axis or centre (*cf.* Revolving).

Rotating is a circular motion of any body about its own axis or centre (*cf.* Revolving, Rolling).

Saturated Mixture (of Air and Vapour) is the term applied to a mixture of air and aqueous vapour at any temperature when the full amount of air and aqueous vapour possible at that temperature. More air might be introduced under increased pressure, but if any more aqueous vapour were added then some must at once liquefy. Any reduction of temperature would cause the deposition of moisture. So that if "dew point" coincides with the given temperature then the air is saturated. Saturated mixtures are of rare occurrence in nature, and in efficient economical artificial drying never used.

Saturated Steam is steam in contact with water at a greater pressure than the atmosphere. Hence they must necessarily both be in a closed vessel.

Saturation of air by vapour is denoted as a percentage of the vapour which would entirely fill the same space at the same temperature if there were no air present. See Humidity.

Scrubber (Gas) is a vessel charged with coke, drain tiles, or other convenient materials for breaking up the currents of gas into minute streams. Being thus cooled, the gas deposits its tar and other liquid components, hence they are generally called "Dry Scrubbers." At coal gas works the scrubber is generally a cast-iron vessel of large diameter, but in producer gas plants it is mostly of wrought steel and smaller in size.

Sensible Heat is the heat which is apparent and capable of measurement by thermometer or pyrometer (*cf.* Temperature).

Shed (Drying). A covered space open for the natural air currents of the surrounding atmosphere to carry away the vapour during drying operations. See Chap. VIII.

Siccative. A moisture absorbent, chiefly used as applied to artistic purposes.

Skin-drying (Moulding). The drying of the *surface* of a green sand mould to diminish the risk of a blown or scabbed casting.

Skinning. Surface drying to form a thin crust of a more impermeable nature than the mass of the material, in order to retain the moisture, *e.g.*, Soap, Pastilles, &c.

Smoke-dried. Applied to goods which are dried by air mixed with the products of combustion (smoke). The hot air causes the vaporisation and drying, but the smoke gives the characteristic flavour and colour. Hence different fuels are used for varied tastes. The main feature is slow drying to obtain the flavour.

Soaked, for the purpose of comparing the humidity of solids and semi-solids, is here used when the water is dispersed abundantly throughout the mass and in the pores of the substance. See Chap. I.

Soluble Driers (Painting) are substances which dissolve in oil and hasten its oxidation. They act very effectively. For instance, manganese linoleate, manganese resinate, lead linoleate, lead resinate.

Sow. A framework of hurdles or light wooden poles into which sheaves of corn are thrust with their heads inwards, for drying purposes. See page 163.

Specific Heat is a relative term, meaning the quantity of heat required to raise a given weight of any substance through a certain range of temperature, *as compared* with the quantity of heat required to raise the same weight of water at 39° Fahr. through the same range of temperature. The specific heat of any solid element varies inversely as its atomic weight, while the specific heat of the same substance varies according to its physical state, being generally greatest in the liquid state, and increases at higher temperatures.

The formula for obtaining the specific heat of body is:—

$$S = \frac{w(\theta - t)}{W(T - \theta)}$$

Where S = Specific heat.
W = Weight of body.
w = Weight of cold water.
T = Temperature of body.
t = Temperature of cold water.
θ = Temperature of the water after body has been removed.

Spits are the thin sticks used in "spitting" fish for drying. They are usually 4½ ft. long by 1 in. thick. Twenty to twenty-five fish are threaded on each spit by passing it under one gill cover of each and out at the mouth.

Steam Bolts (Dyeing) are various shaped hollow heads (paw, egg, mushroom, tapered, plain, &c.) used for drying and finishing of dyed goods. They are fixed on stands in various sets and have steam heating connections.

Steam Dryer is an apparatus for removing the water from live steam, *e.g.*, the water from priming or condensation in the valves, pipes, or cylinders. Dry steam is in every respect more efficient and safer. Other names for the same apparatus are Separator, Interceptor, and Catchwater.

Steam Trap is an apparatus to retain exhaust steam till it is condensed to water, or to allow of condensation water passing away without the escape of steam.

Stenter (Textile). Same as Tenter (*q.v.*).

Still Air. Used in connection with insulation to denote the air which remains quite motionless, as distinguished from "confined" air, which is merely shut up. Confined air may circulate in the confined space and so pass the heat by convection. See page 104.

Stove. A closed or partly closed vessel or receiver in which fuel is burned. Portable, as distinguished from furnace. Hence *a drying stove* is a portable apparatus in which fuel is burned to dry by direct heat. See Chap. IX.

Stoving. Applied to removing other vapours than water by means of heat in a stove, *e.g.*, enamelling, japanning.

Stoving (Textile). Drying in hot air as distinguished from the cylinder-drying.

Sublimation. Some substances, when heated, are converted immediately into vapour without assuming the liquid form and without any chemical change. They are then said to *sublime*.

Sun-cracks (Geology) are desiccation cracks (*q.v.*).

Superheated Steam is steam heated away from the presence of water and hence not containing, because not able to obtain, the amount of water which its temperature would carry.

Superheated Vapour is the vapour in a space which contains less moisture than its temperature would allow. Any vapour which is not saturated really contains a larger quantity of heat than is necessary to sustain itself as vapour.

Sweat (Barley). The heating and partial drying of barley.

Symbols.

W = Weight in lb.
V = Volume in cubic feet.
T = Temperature Fahrenheit.
P = Pressure in lb. per square inch.
F = Elastic force in inch of mercury.
E = Coefficient of expansion.
S = Specific heat as to water.
H = Humidity.
B = Heat in B.Th.U.
J = Joules.
L = Latent heat.
Fahr.° = Degree Fahrenheit.
Cent.° = Degree Centigrade.

a = Wet material.
b = Dry material.
c = Water to be extracted.
d = Aqueous vapour.
e = Dry air.

f = External air.
g = Air from heater.
h = Air from condenser.
i = Air from dryer.
m = Mixture of air saturated with vapour.

Syphon Gauge is a gauge to test the air pressure in ducts and flues by the varying pressure in the two arms of a glass syphon. See page 96 and Table XV.

Tellerofen (German). A plate oven or stove (*e.g.*, Rieckert's) as series of superimposed plate-like shelves. See pages 245-7.

Temperature. The temperature or hotness of a body may be defined as being the greater or less extent to which it tends to impart heat to other bodies. The temperature of a body, which is the degree of its sensible heat, must not be confounded with the quantity of heat it possesses (*cf.* Calorimetry). Temperature is measured by thermometers of mercury at ordinary temperatures, of spirit for low temperatures, and by pyrometers of metal or clay for high temperatures.

Tension is the term sometimes applied to the elastic force of vapour or gases. Tension is a pull. Gases cannot pull, but they are constantly *pushing* in all directions, therefore they are in a state of *pressure* (*q.v.*).

Tenter-frame. A frame or machine on which fabrics are stretched by hooks, generally during the process of drying. See Fig. 81.

Therm was suggested by the British Association in 1888 as the amount of heat required to raise the temperature of 1 gramme of water from 0° Cent. to 1° Cent. It therefore equals $\frac{1}{1000}$ of a calorie (*q.v.*).

$$1,000 \text{ Therms} = 1 \text{ Calorie} = 3·968 \text{ B.Th.U.}$$

Thermometer Scales. With a normal atmospheric pressure of 29·921 in. of mercury pure water solidifies when it has a definite quantity of heat, and also boils when it has another larger definite quantity of heat. These two states are taken as fixed points in order to obtain a unit of comparison for all other states and all other materials. The freezing point has been called 32° by Fahrenheit, who then divide the quantity to boiling point into 180 parts, fixing 212°, so that 1° on his scale $= \frac{1}{180}$ part of the heat required to raise pure water just melted from ice to water just commencing to boil. By the French system, called Centigrade, this same quantity of heat is divided into 100°, and with freezing point marked as 0°, of course boiling point becomes 100° Cent. Reaumur's Scale, used in Russia, divides these two critical points into 80 parts, and therefore, while freezing point is 0° Reaum., the boiling point is 80° Reaum. Hence—

$$120° \text{ Fahr.} = 100° \text{ Cent.} = 80° \text{ Reaum.}$$

$$6° \text{ Fahr.} = 5° \text{ Cent.} = 4° \text{ Reaum.}$$

$$\frac{\text{Fahr.} - 32}{180} = \frac{\text{Cent.}}{100} = \frac{\text{Reaum.}}{80}$$

Thermostat is an instrument to respond quickly to any changes in the hygrometric conditions, and so regulate the apparatus for humidifying or drying the air.

Torrefiers (Barley) are heating apparatus to dry barley, &c., by hot air currents.

Total Heat is the quantity of heat (in units) necessary to raise a substance to a given temperature and vaporise it at that temperature. Equals latent heat plus sensible heat.

Formula.—To calculate the total heat required to evaporate water at a given temperature.

$$B = 1082 + ·305T.$$

Where B = Heat in B.Th.U.,

T = Given temperature.

Tunnel (Drying) is a tunnel through which material passes during the operation of drying.

Units. Used in connection with drying and desiccating machinery calculations.

For Heat—B.Th.U., Calorie, Therm.
„ Temperature—Fahr., Cent., Reaum.
„ Weight—Lb., Kilogramme.
„ Mechanical Equivalent—Foot-pounds, J or Joules.
„ Volume—Foot, Metre, Gallon, Litre.
„ Pressure—Lb. per Sq. Foot, Kilos. per Sq. Centimetre.
„ Electrical Energy—B.T.U.

Unwater. To remove the *water* from the surface and from between the particles. (Mineralogical) to drain a mine.

Unwatering is removing the surface water and the free water from solid materials of an open porous nature.

Vacuum Process of Drying is the plan of drying when the receptacle in which the wet material is placed has its air abstracted to a considerable degree, and the vapour withdrawn without the intervention of air. See Chap. VI.

Vaporimeter. An instrument for determining the vapour-pressure (*cf.* Evaporometer).

Vaporisation is the change of a liquid into the gaseous or vaporiform state. When the process is rapid, and throughout the mass of the liquid, it is termed ebullition or boiling (*q.v.*). When it proceeds from the free surface and the vapour passes off it is called evaporation (*q.v.*).

Vaporiser. An apparatus to reduce any substance to vapour (*cf.* Atomiser).

Vaporising Stove. A portable stove for supplying vapour (steam) to a greenhouse (*cf.* Humidifier).

Vapour and Gas have no essential difference of meaning, but vapour is generally applied to the gaseous condition of bodies which are usually met with in the liquid or solid state, *e.g.*, water, sulphur, ether, &c., and is sometimes further restricted in its application to the gaseous condition when produced by surface evaporation as distinguished from steam which is produced by ebullition.

Vapour Depositor. An apparatus for causing the condensation and deposition of the vapour in an air current by refrigeration. See Fig. 14.

Water. See Water of Combination, Water of Crystallisation, Water of Manufacture, Hygroscopic Water, Quarry Water, Water of Deliquescence, Incidental Water, Accidental Water.

Water Eliminator.	An apparatus for removing the water-spray from refrigerated air. A series of zigzag baffles placed in the track of the air current if possible at a point of high velocity.
Water-Extractors.	A term sometimes applied to hydro-extractors but not commonly so used.
Water-freed.	Usually applied to liquids which have had their water removed, *e.g.*, water-freed alcohol.
Water-logged	Rendered log-like or unmanageable through being filled with water.
Water of Combination	is the water chemically united (or combined) with the material, and is essential to its then condition, *e.g.*, the water in the sap of trees, the juice of fruits.
Water of Crystallisation.	The water which unites chemically with many salts during the act of crystallisation. It forms an essential part of the crystal but not of the salt, and is easily expelled by heat, when the crystals generally fall to powder. The powder still contains the water of combination (*q.v.*), *e.g.*, cupric sulphate when heated to 212° Fahr. loses its crystalline form and blue colour, four molecules of water being expelled; to expel the fifth molecule (water of combination) a temperature of 467° Fahr. is necessary.
Water of Deliquescence.	The water taken up by deliquescent bodies when exposed to the atmosphere.
Water of Manufacture.	The water necessarily used with materials during the course of manufacture, but not required in the finished product.
Water Oven.	An oven encased with a water jacket used for heating and drying.
Water-soak.	To soak or fill the interstices of any substance with water.
Water-sodden.	Rendered soft by the water soaked into it.
Wet,	for the purpose of comparing the humidity of solids and semi-solids, is here used when the water is abundant, but mainly on the surface or mixed with the particles. See Chap. I.
Whizzer.	A term applied to centrifugals (hydro-extractors), especially those used for grains. See Fig. 28.
Wither (Tea).	The drying of tea.

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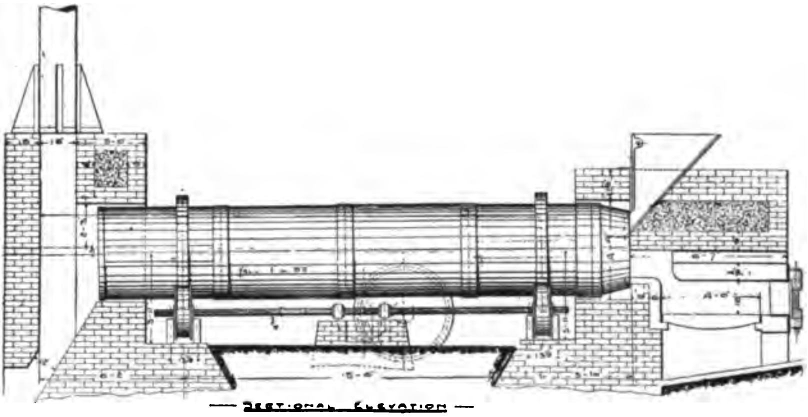

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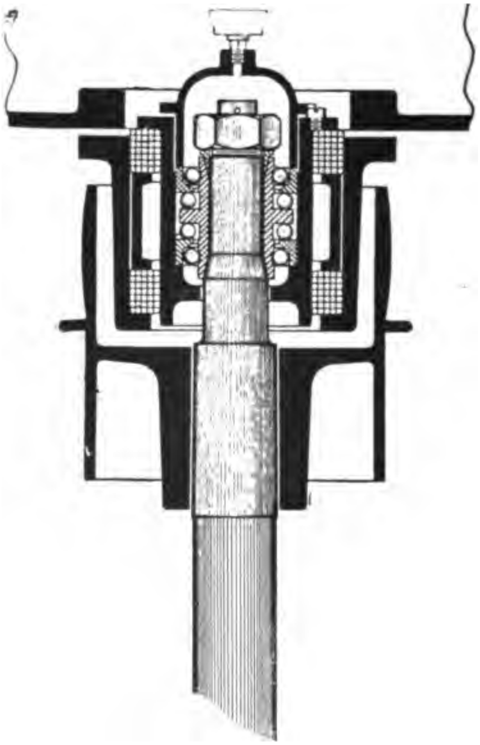

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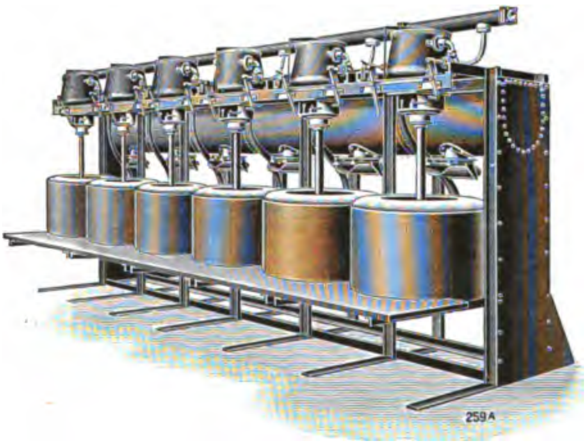

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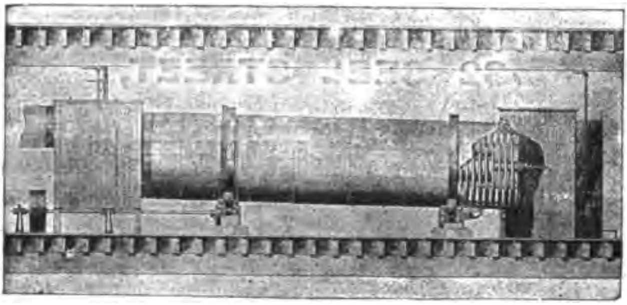

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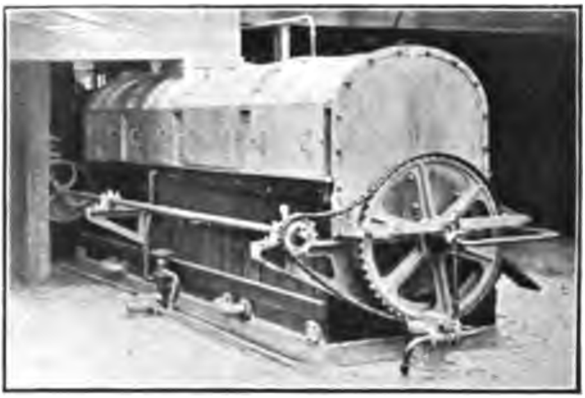

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A selection of illustrations of centrifugal drying machines are shown on opposite page. If you are interested, please ask for book of special designs, which gives full particulars.

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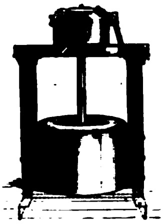
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"Vanawate" Water Drive.

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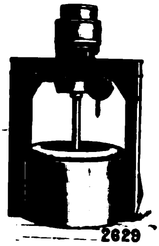
"Vanaside" Belt Drive.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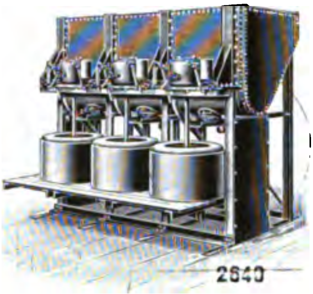
"Vanamote" Electric Drive.

2638
Belt-driven Centrifugals with Feeding Trough.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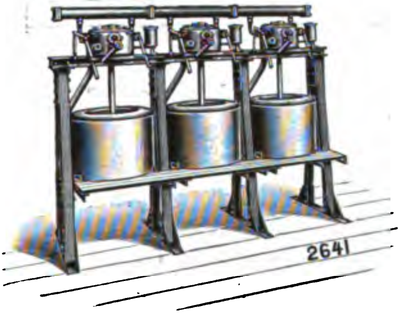
Water-driven Centrifugals with large Mixer.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Water-driven Centrifugals with Steel Framing.

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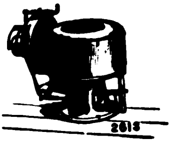
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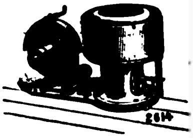
"Vindanda"
Belt Drive.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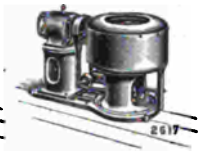
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"Vintric"
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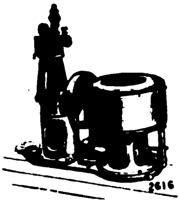
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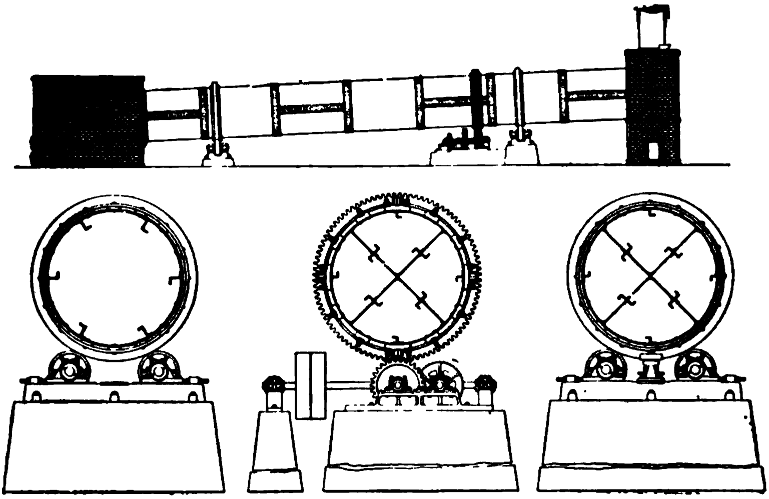

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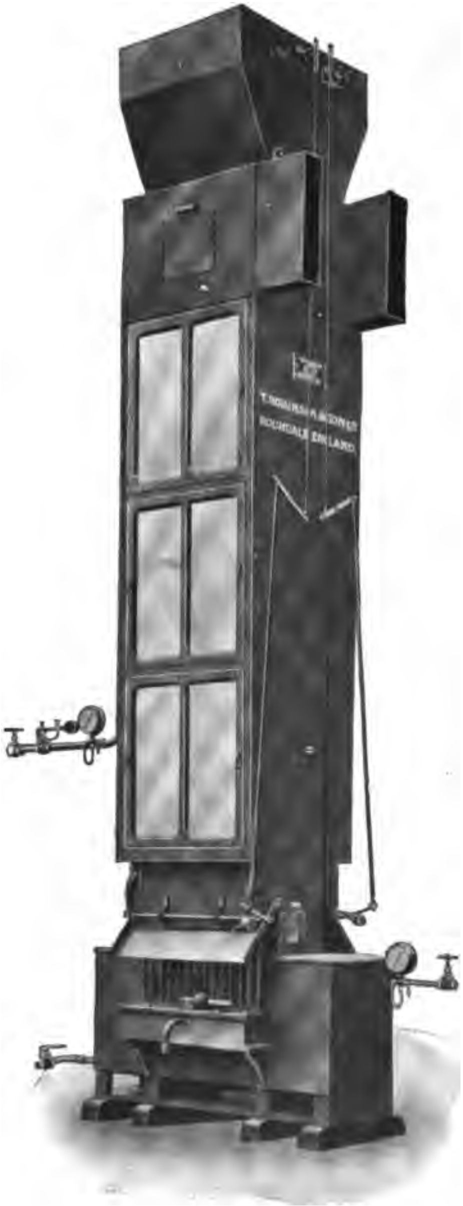

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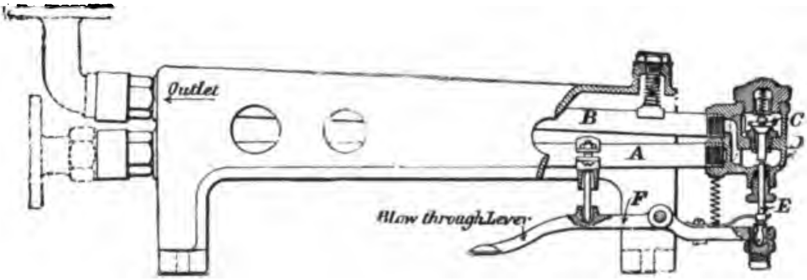

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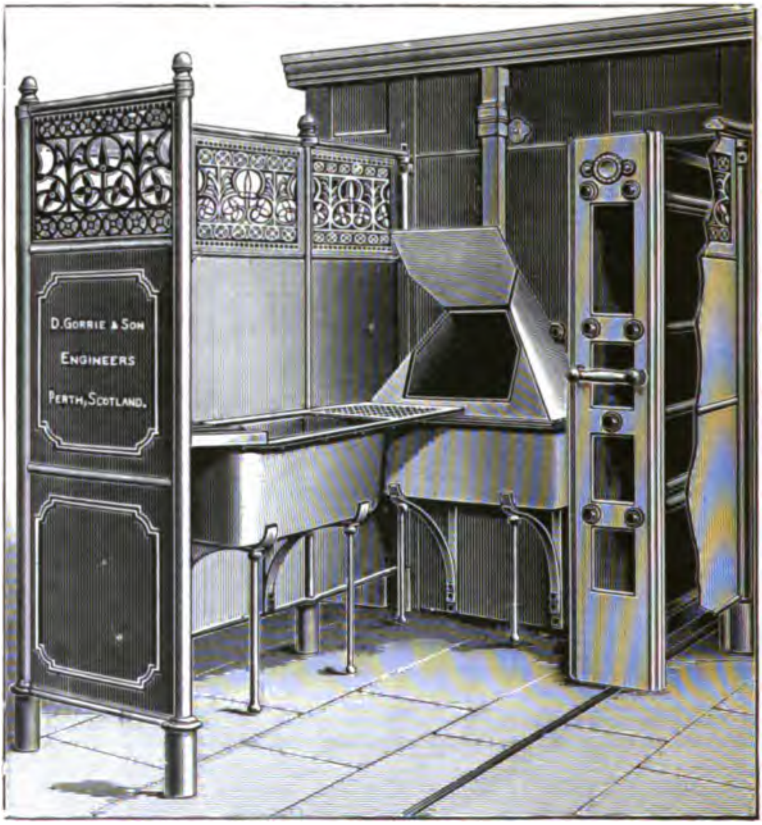

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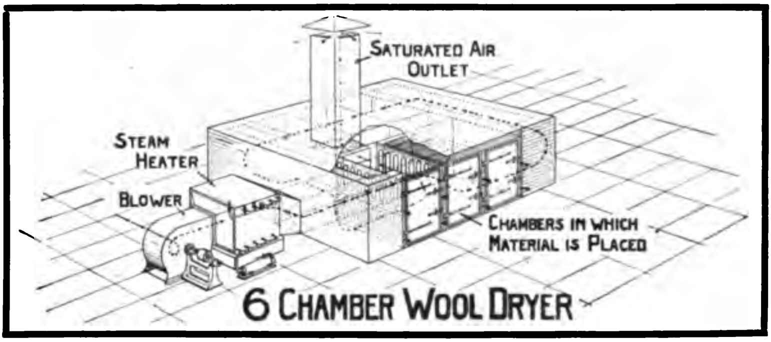

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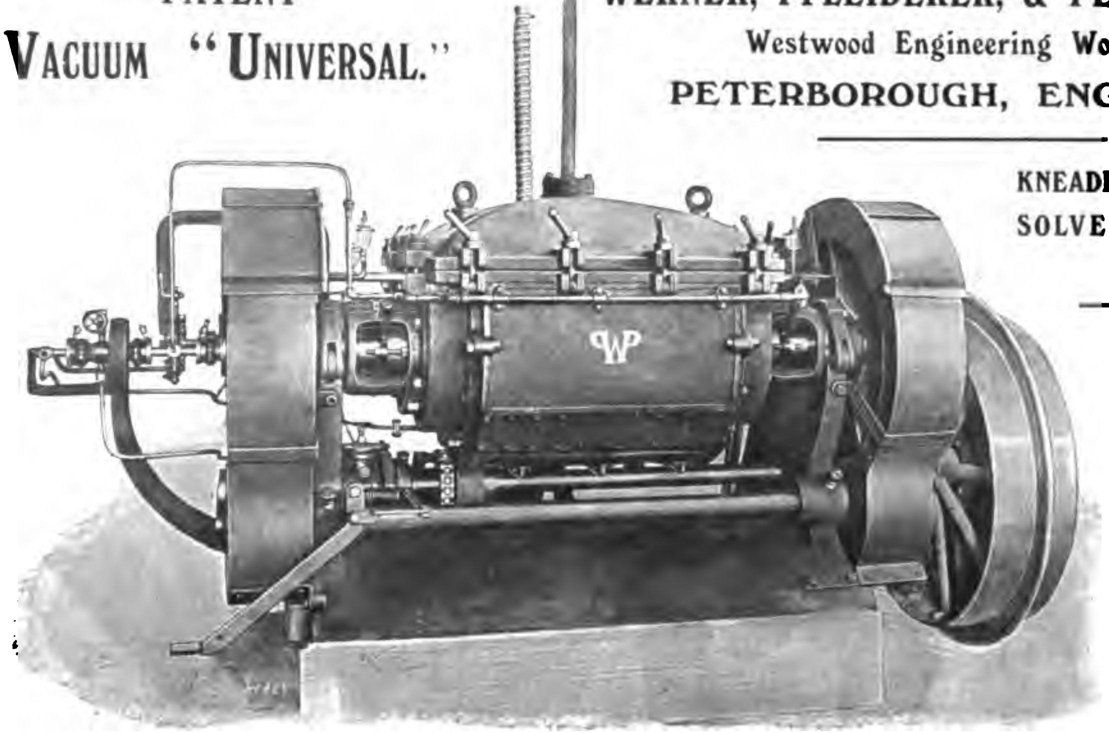

Fig. 847.—This shows the machine in working position; it can be tilted over for emptying.

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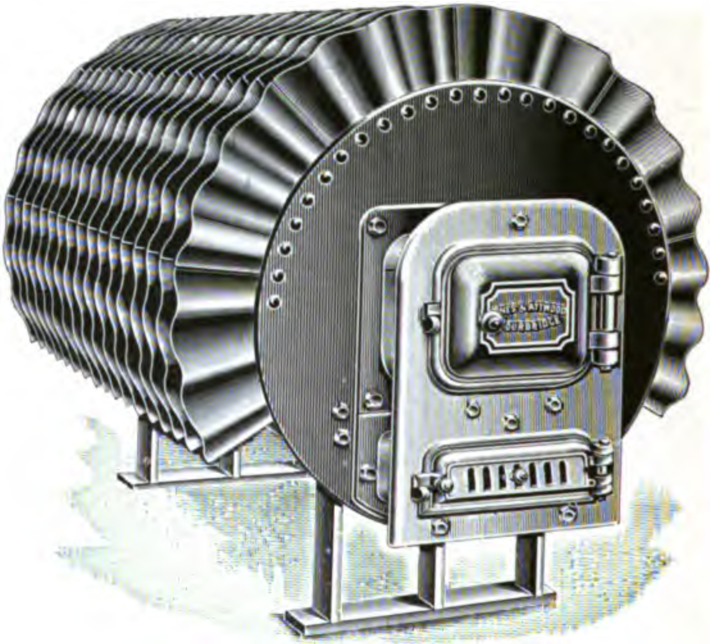

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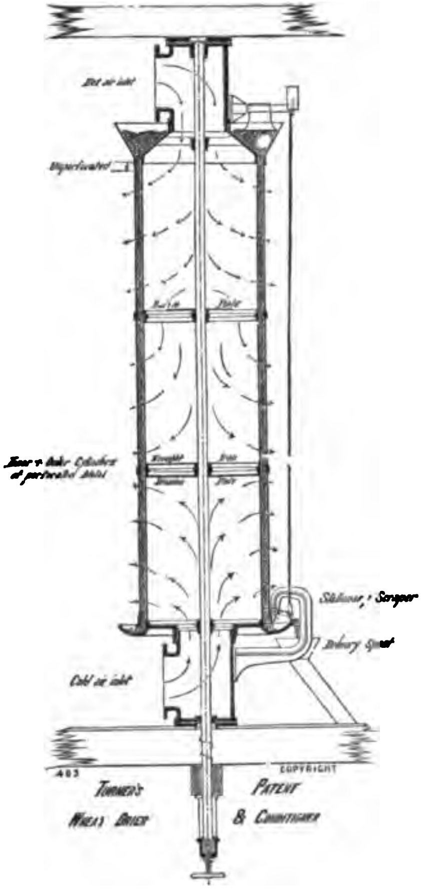

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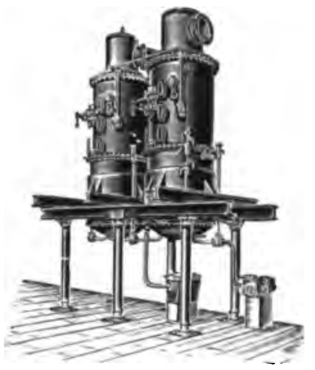

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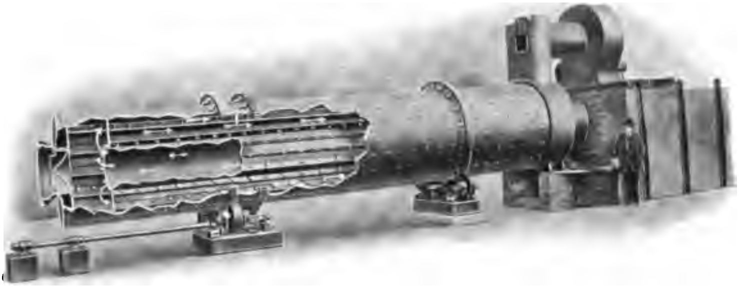

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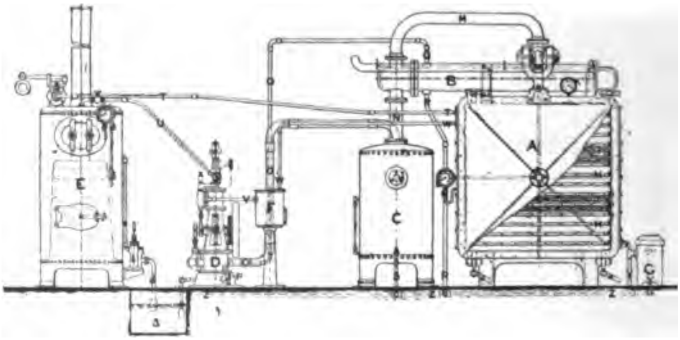

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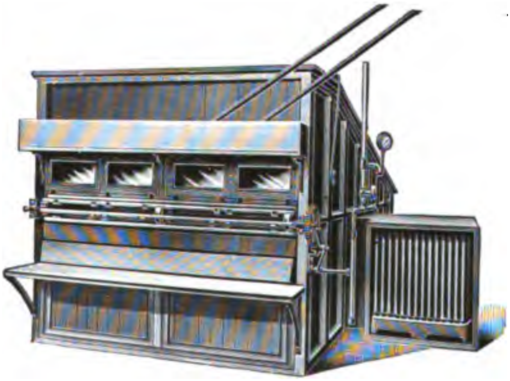

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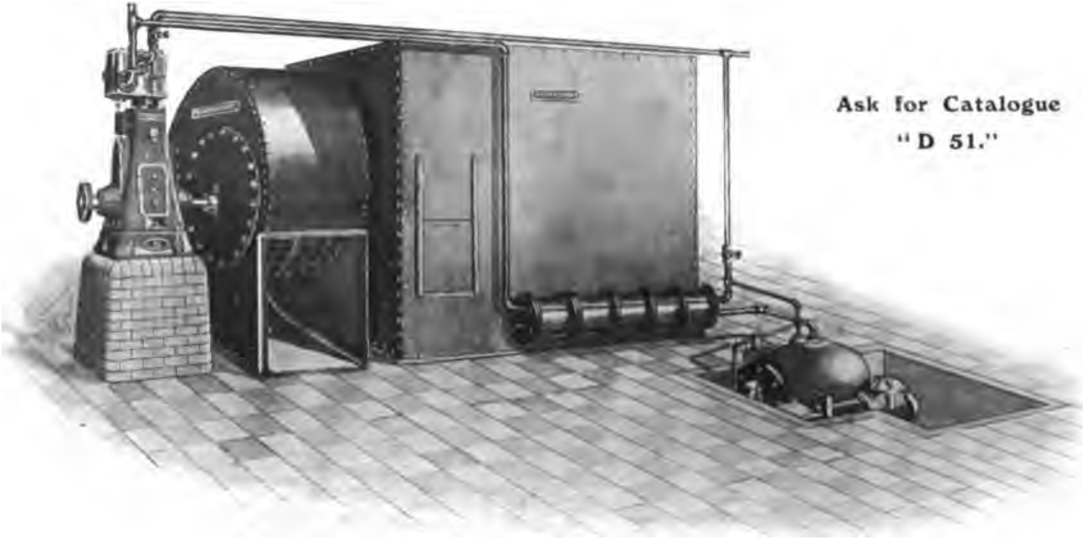

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